State of Minnesota
Technical Reference Manual
for
Energy Conservation Improvement Programs

Version 1.2

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Minnesota Department of Commerce
Division of Energy Resources

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Acknowledgements

This document was primarily constructed from energy efficiency and conservation measure specifications developed by Franklin Energy Services with input from Minnesota Department of Commerce, Division of Energy Resources staff and Minnesota utilities. Commerce staff appreciates the significant contributions that Minnesota utilities, consultants, and other stakeholders have made to the Technical Reference Manual (TRM) through sharing information and participating in TRM advisory committee and technical work group meetings.

Purpose and Use of Manual

The purpose of this technical reference manual (TRM) is to put forth standard methodologies and inputs for calculating the savings impacts and cost-effectiveness of energy conservation improvement programs (CIP) in Minnesota. The TRM also documents the calculations that are embedded in the Minnesota Department of Commerce, Division of Energy Resources (DER) TRM Smart Measure Library on ESP®[1], a set of working models for real time savings calculations and tracking that is available to all Minnesota utilities on ESP®.

The TRM is not intended to define a single set of approved calculation methods; rather, the TRM is a standard set of methodologies and inputs that CIP administrators may reference when developing, implementing and reporting on CIP programs. Each measure herein represents a pre-approved calculation method when correctly applied in a program. While Commerce encourages utilities to use the TRM measure designs, utilities may propose, with justification, variations that reflect different program designs or enhanced calculation methods that will result in more accurate savings estimations. Utilities may also use the TRM to generate tables of unitary "deemed savings" figures for pre-defined pre- and post- equipment combinations, if their current tracking software requires this format.

Similarly, the TRM does not represent an exclusive set of measures that may be applied in CIP programs. Minnesota utilities may propose additional measures as standard offerings in their CIP plans, or implement custom measures without pre-approval from Commerce.

[1] ESP® is Cloud-based software application for energy efficiency program management and reporting developed by Energy Platforms, LLC with funding from the Minnesota Department of Commerce. ESP® is launched from www.energyplatforms.com. All Minnesota utilities are granted free access to all features within ESP®. Contact Commerce staff at CIP.Contact@state.mn.us to obtain a login to ESP®.

Electric Efficiency Measures

C/I HVAC - Chiller Systems

Version No. 1.3

Measure Overview

Description:

This measure analyzes the space cooling savings potential of the installation of high efficiency chillers including; all air cooled chillers, water cooled screw, scroll, and centrifugal chillers.

This measure is applicable to chillers with efficiencies provided at AHRI conditions, but also accommodates water cooled centrifugal chillers with efficiencies provided at other conditions.

The incremental cost is associated with base equipment cost and does not include any installation costs.

Actions: Replace on Fail, Replace Working or New Construction.
Target Market Segments: Commercial, Industrial
Target End Uses: HVAC

Applicable to: Commercial & Industrial customers where chillers can be installed to meet space cooling requirements.

Algorithms

Unit kWh Savings per Year = Nominal Capacity x (IPLV_base - IPLV_EE) x EFLH_cool

Unit Peak kW Savings = Nominal Capacity x (FLV_base - FLV_EE) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 20 years (ref 1)

Unit Participant Incremental Cost = See Table 1

Where:

Capacity = the nominal rating of the cooling capacity of the energy efficient chiller (tons)

IPLV_EE = the integrated part load value (IPLV) of the energy efficient chiller (KW/ton) at AHRI standard conditions*

= IPLV_CS / K_adj = the integrated part load value of energy efficient chiller at operating conditions divided by k_adj for water cooled centrifugal chillers if new chiller not AHRI-rated

IPLV_base = the integrated part load efficiency of the baseline chiller (kW/ton), IPLV_base = IPLV_AHRI per Table 1.

EFLH _cool = the equivalent full load hours of cooling per zone from Table 2 per building type

FLV_EE = the equivalent full load value of the energy efficient chiller (kW/ton), FLV at AHRI standard conditions*provided by the contractor/customer.

= FLV_CS / k_adj = the equivalent full load value of the energy efficient chiller at operating conditions divided by k_adj for water cooled centrifugal chillers if new chiller not AHRI-rated

FLV_base = the full load efficiency of the baseline chiller (kW/ton), FLV_base = FLV_AHRI per Table 1.

CF = Deemed coincident demand factor, equal to 0.90 (Ref. 2)

For Water Cooled Centrifugal Chillers not tested at AHRI Standard Conditions** (ref. 3):

IPLV_CS = for water cooled centrifugal chillers not tested at AHRI Standard test conditions*, the integrated part load value provided by customer/contractor at operating conditions (kW/ton)

FLV_CS = for water cooled centrifugal chillers not tested at AHRI Standard test conditions*, the equivalent full load value provided by customer/contractor at operating conditions (kW/ton)

k_adj = 6.1174722 - 0.303668 (X) + 0.00629466 (X) ^ 2 - 0.000045780 (X) ^ 3

X= DT_std + LIFT

DT_std= (24 + (FLV_CS X 6.83)) / Flow

LIFT = Entering condenser water temperature (°F) minus the leaving chilled water temperature (°F), supplied by the customer/contractor.

Flow = Condenser water flow (gpm) / Cooling full load capacity (tons)

* Standard AHRI test conditions are 44°F leaving chilled water temperature, 85°F entering condenser water temperature with 3 gpm/ton condenser water flow and 2.4 gpm evaporator water flow.

** These adjustment factors are applicable to centrifugal chillers designed for a minimum leaving water temperature of at least 38°F, a maximum condenser entering water temperature of 102 °F or less and a condenser water flow of 1 to 6 gpm/ton.

Required from Customer/Contractor: New chiller type, nominal cooling capacity in tons, integrated part load value, full load value; building type (refer to Table 2), project location (county)

- Chilled water leaving temperature, condenser entering temperature and condenser gpm; if water cooled centrifugal chiller is not AHRI rated.

Example:

Retrofit of an existing water cooled centrifugal chiller installed in a Hospital, unrated 600 ton cooling capacity, Design FLV = 0.50, Design IPLV of 0.45, Climate Zone 3.

The condenser water entering temperature is 80°F with a flow rate of 1500 gpm. The chilled water supply temperature is 40°F.

Lift = 80°F - 40°F = 40°F

DT_std = (24 + (0.50 X 6.83)) / (1500 / 600) = 11°F

X = 11 + 40 = 51°F

K_adj = 6.147422 - 0.303668 X 51 + 0.00629466 X (51) ^ 2 - 0.000045780 X (51) ^ 3 = 0.96

FLV_EE = 0.50 / 0.96 = 0.52

IPLV_EE = 0.45 / 0.96 = 0.47

*Unit KWh Savings per Year = 600 * (0.58 - 0.52) * 1298 = 46,728 KWh*

*Unit Peak KW Savings per Year = 600 * (0.55 - 0.47) * 0.9 = 43.2 KW*

Deemed Input Tables:

Table 1: Deemed Full Load and Integrated Part Load Baseline Efficiencies per AHRI 550/590 and Incremental Costs (ref. 4, 5)

Equipment	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)	Incremental Cost ($/ton)
Water Cooled Scroll or Screw Chiller < 150 tons	0.79	0.68	130
Water Cooled Scroll or Screw Chiller ≥ 150 and < 300 tons	0.72	0.63	90
Water Cooled Scroll or Screw Chiller ≥ 300 tons	0.64	0.57	40
Water Cooled Centrifugal Chiller < 150 tons	0.70	0.67	130
Water Cooled Centrifugal Chiller ≥ 150 and < 300 tons	0.63	0.60	85
Water Cooled Centrifugal Chiller ≥ 300 tons	0.58	0.55	40
Air Cooled Chiller with Condenser***	1.26	1.15	110

**** FLV_AHRI = 12 / EER and IPLV_AHRI = 12 / SEER*

Table 2: Equivalent Full Load Hours of cooling per zone in Minnesota by building type (ref. 6)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	647	825	986
Education - Community College/University	682	782	785
Education – Primary	289	338	408
Education – Secondary	484	473	563
Health/Medical – Clinic	558	738	865
Health/Medical – Hospital	663	1089	1298
Lodging	401	606	754
Manufacturing	347	472	589
Office-Low Rise	257	359	446
Office-Mid Rise	373	529	651
Office-High Rise	669	1061	1263
Restaurant	347	535	652
Retail - Large Department Store	462	588	686
Retail - Strip Mall	307	441	574
Warehouse	164	343	409

Table 3:Future Deemed Full Load and Integrated Part Load Baseline Efficiencies per ASHRAE 90.1 -2010

	PATH A****		PATH B*****	
Equipment	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)
Water Cooled Scroll or Screw Chiller < 75 tons	0.78	0.63	0.80	0.60
Water Cooled Scroll or Screw Chiller ≥ 75 and < 150 tons	0.78	0.62	0.79	0.59
Water Cooled Scroll or Screw Chiller ≥ 150 and < 300 tons	0.68	0.58	0.72	0.54
Water Cooled Scroll or Screw Chiller ≥ 300 tons	0.62	0.54	0.72	0.54
Water Cooled Centrifugal Chiller < 150 tons	0.63	0.60	0.64	0.45
Water Cooled Centrifugal Chiller ≥ 150 and < 300 tons	0.63	0.60	0.64	0.45
Water Cooled Centrifugal Chiller ≥ 300 and < 600 tons	0.58	0.55	0.60	0.40
Water Cooled Centrifugal Chiller ≥ 600 tons	0.57	0.54	0.59	0.40
Air Cooled Chiller with Condenser < 150 tons	1.26	0.96	NA	NA
Air Cooled Chiller with Condenser > 150	1.26	0.94	NA	NA

***** Path A is for traditional applications and where the intended applications are expected to have significant operating times at full load conditions.*

****** All Path B chillers must be equipped with demand limiting controls.*

Methodology and Assumptions:

EFLH_Cool data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Assumed ventilation rates complied with the requirements of ASHRAE standard 62.1 – 2004.

Notes:

Savings are based upon AHRI rated chillers and those water cooled centrifugal chillers operating within the limits of the nonstandard conditions listed above.

Table 3 chiller sizes were expanded to cover the intent of ASHRAE standard 90.1 - 2010, Table 6.8.1.C, Water Chilling Packages - Minimum Efficiency Requirements

References:

1. ASHRAE, 2007, Applications Handbook, Ch. 36, table 4, Comparison of Service Life Estimates

2. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, and primary data has not been identified.

3. Addendum m to ASHRAE 90.1 -2007, 2008 Supplement, Energy Standard for Buildings except Low-Rise Residential Buildings

4. ASHRAE 90.1 - 2004, Energy Standard for Buildings except Low-Rise Residential Buildings, Table 6.8.1.C, Water Chilling Packages - Minimum Efficiency Requirements

5. 2008 Deer www.deeresources.com - Average across Tier 1 equivalent equipment.

6. Calculated through energy modeling by FES.

Documentation Revision History:

Version	Description	Author
1	New specification replacing ChillersAirCooled_v03 and ChillersCentrifugal_v03. Followed methodology in Xcel Energy 2010-2012 CIP Plan (Docket No. E,G002/CIP-09-198)	JP
1.1	Changed 'Equivalent' to 'Equivalent' for Table 1.	SK
1.2	Revised format to customer's current requirements. Updated Nonstandard conditions calculations. Revised hours in Table 2. Added/updated references 3, 5 and 6. Updated incremental costs. Reordered references and tables to make them sequential. Added Table 3.	FES
1.3	Changed 'ARI' to 'AHRI' throughout, wording changes	JP

C/I HVAC - Heat Pump Systems

Version No. 1.0

Measure Overview

Description:

This measure includes replacement of non-working and working unitary air source heat pump (ASHP), ground water source heat pump (GWSHP) and ground source heat pump (GSHP) equipment.

This measure analyzes the heating and cooling savings potential of the installation of higher efficiency unitary heat pump equipment.

The incremental cost is associated with base equipment cost and does not include any installation costs.

Actions: Replace on Fail, Replace Working or New Construction.
Target Market Segments: Commercial & Industrial
Target End Uses: HVAC

Applicable to: Commercial & Industrial customers where heat pump unitary equipment can be installed.

Algorithms

Unit kWh Savings per Year (ASHP units less than 5 tons) **=** Size x EFLH_cool x (12 / SEER_Base - 12 / SEER_EE) + (Size x HDD65 x 24 x Correction Factor x (1 / (ΔT)) x (12/HSPF_base - 12/HSPF_EE)

Unit kWh Savings per Year **=** Size x EFLH_cool x (12 / SEER_Base - 12 / SEER_EE) + (Size x HDD65 x 24 x Correction Factor x (1 / (ΔT)) x (3.52 / COP_base - 3.52 / COP_EE)

Unit Peak kW Savings = Size x (12/EER_Base - 12/EER_EE) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years (ref 1)

Unit Participant Incremental Cost = See Table 3 (ref. 2) or Table 4 (ref 3)

Where:

CF = Deemed coincidence factor, equal to 0.9 (ref. 4)

Correction Factor = correction factor, assumed to be 0.7 (ref. 5)

COP_base = Heating system performance factor of baseline or existing ASHP, provided by customer/contractor. If unknown see Table 3 (ref. 6)

COP_EE = Heating system performance factor of efficient ASHP, provided by customer/contractor

EER_base = Energy efficiency ratio of the baseline equipment, based on Federal minimal efficiency ratings. See Table 3 (ref. 7)

EER_EE = Energy efficiency ratio of the high efficiency equipment, provided by the customer. If unknown, use EER = 0.875 x SEER (ref. 8)

EFLH_cool = Effective full load cooling hours based on the building type. See Table 1. (ref. 8)

HDD65 = Heating Degree Days, see Table 2. (ref 9)

HSPF_base = Heating system performance factor of baseline or existing ASHP, provided by customer/contractor or use HSPF_base = 7.7 if unknown (ref. 6)

HSPF_EE = Heating system performance factor of efficient ASHP, provided by customer/contractor

Size = Nominal Cooling capacity in tons of the new equipment (1 ton = 12,000 btu/h)

SEER_base = Seasonal energy efficiency ratio of the baseline equipment, based on federal manufacturing requirements. See Table 3 (ref. 7)

SEER_EE = Seasonal energy efficiency ratio of the high efficiency equipment, provided by the customer/contractor. If unknown, use SEER = EER / 0.875 (ref. 5)

ΔT = Difference in temperature (°F) between the return air conditions (ref. 10) and the design day outside air conditions (ref. 11). See Table 1 for default values if not provided.

Required from Customer/Contractor: Equipment size (tons), SEER or EER of new equipment, SEER or EER of existing equipment (if program includes early replacements), HSPF of new equipment, HSPF of existing equipment (if program includes early replacements), existing equipment condition (working or failed, if program includes early replacements), building type (see Table 1), project location (county)

Example:

New ASHP packaged rooftop installed in midrise office, 7.5 ton cooling capacity, EER 14 and COP 0f 3.4, Climate Zone 3.

*Unit KWh Savings per Year = 7.5 * 651 * [(12 / 12.6 - 12 / 14)] + 7.5 * 7651 * 24 * 0.7 * (1/ (70.0 - (-14.5)) * (3.52 / 3.2 - 3.52 / 3.4) = 1203 KWh*

*Unit Peak KW Savings per Year = 7.5 * (12 /12.6 - 12 / 14) * 0.9 = 0.64 KW*

Deemed Input Tables:

Table 1: Equivalent Full Load Hours of cooling per zone in Minnesota by building type (ref. 8)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	647	825	986
Education - Community College/University	682	782	785
Education - Primary	289	338	408
Education - Secondary	484	473	563
Health/Medical - Clinic	558	738	865
Health/Medical - Hospital	663	1089	1298
Lodging	401	606	754
Manufacturing	347	472	589
Office-Low Rise	257	359	446
Office-Mid Rise	373	529	651
Office-High Rise	669	1061	1263
Restaurant	347	535	652
Retail - Large Department Store	462	588	686
Retail - Strip Mall	307	441	574
Warehouse	164	343	409

Table 2: Design temperatures, default heating return temperatures, and heating degree-days (HHD65)

Zone #	Design Temp. Heating (°F) (ref. 10)	Default Heating Return Temp. (°F) (ref. 11)	HDD65 (ref. 9)
Northern: #1	-22.0	70.00	9833
Central: #2	-16.5	70.00	8512
Southern: #2	-14.5	70.00	7651

Table 3: Deemed baseline efficiency for heating and cooling, incremental costs

Equipment	SEER_base (ref. 6)	EER_base (ref. 6)	HSPF_base (ref. 6)	COP_base (ref. 6)	Incremental Cost (ref. 2)
ASHP Units less than or equal to 5.4 tons*	13.0	11.4	7.7	-	See Table 4
ASHP Units 5.5-11.3 tons*	12.6	11.0	-	3.3	$165/ton
ASHP Units 11.4-19.9 tons*	12.1	10.6	-	3.2	$150/ton
ASHP Units 20-63.3 tons*	10.9	9.5	-	3.2	$140/ton
GSHP Units (closed loop)**	15.3	13.4	-	3.1	$150/ton
GWSHP Units (open loop)**	18.5	16.2	-	3.6	$150/ton

*HSPF and COP based upon 17°F DB and 15°F WB Outdoor air temperature.

** Cooling and Heating efficiencies based upon ASHRAE 90.1-2010.

Table 4. ASHP units 5.4 tons or less Incremental cost (ref. 3)

Efficiency Level	Incremental Cost
SEER 14	$137/ton
SEER 15	$274/ton
SEER 16	$411/ton
SEER 17	$548/ton
SEER 18	$685/ton

Methodology and Assumptions:

EFLH_cooling was determined from TMY3 data for cities within the particular zones.

Assumed ventilation rates complied with the requirements of ASHRAE standard 62.1 - 2004.

Notes:

Base line ground source heat pump SEER is based upon an entering temperature of 59 deg. F entering water temperature.

References:

1. "Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", by GDS Associates, Inc. June 2007, pg. 6

2. Comparison of Electric/Gas Fired Unitary equipment costs from DEER 2008 Database Technology and Measured Cost Data and Electric/Gas Fired Unitary and Heat Pump equipment costs from RSMeans Mechanical Cost Data

3. DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com)

4. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.

5. The correction factor corrects heating usage as building balance points are below 65F, and setback schedules are common. A typical heating degree day correction factor is 0.7. Assuming a typical building balance point temperature of 55F if was found that for a sampling of Minnesota cities HDD55 = 0.7 x HDD65.

6. Title 10, Code of Federal Regulations, Part 431 - Energy Efficiency Program for Certain Commercial and Industrial Equipment, Subpart F - Commercial Air Conditioners and Heat Pumps. January 1, 2010.

7. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment

8. Calculated through energy modeling by FES 2012

9. National Climate Data Center - National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.

10. Assumed heating set point of 70°F, FES

11. 2009 ASHRAE Handbook HVAC Fundamentals

Documentation Revision History:

Version	Description	Author	Date
1	New deemed savings specification replacing/utilizing Heat Pump Units.	FES	
1.1	Corrected table references, Required Inputs	JP	6/6/14

C/I HVAC - High Volume Low Speed Fans

Version No. 1.1

Measure Overview

Description: This measure applies to the installation of large horizontally mounted high volume low speed (HVLS) fans to replace multiple smaller, non HVLS fans in commercial, industrial, or agricultural facilities.

Actions: Replace on Fail, Replace Working, New Construction

Target Market Segments: Commercial, Industrial

Target End Uses: HVAC

Applicable to: Commercial, industrial, or agricultural customers that currently use non HVLS fans

Algorithms

Unit kWh Savings per Year = kWh_base - kWh_EE

Unit Peak kW Savings = Unit kWh Savings per Year x CF / Hrs

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years (Ref. 1)

Unit Participant Incremental Cost = Refer to Table 3

Where:

kWh_Base = Hrs x Qty_Base x kW_Base

kWh_EE = Hrs x kW_HVLS

Hrs = Assumed annual operating hours of fans (Refer to Table 1)

Qty_HVLS = the quantity of HVLS fans being installed. The default value is 1 (per unit basis).

Qty_Base = the quantity of baseline fans that would be replaced with HVLS fans. Assumed to be 5 standard fans per HVLS fan. (Ref. 3)

kW_HVLS = The rated input Wattage of each HVLS fan, assumed to be 1.0 kW (Ref. 4)

kW_Base = The rated input Wattage of each non-HVLS fan, assumed to be 1.0 kW (Ref. 4)

CF = Peak coincidence factor = 0.9 (Ref. 5)

Required from Customer/Contractor: Size (diameter) of HVLS fans being installed, facility use type.

Example:

A 20-foot HVLS fan is installed to replace five standard fans, used to provide air circulation in a manufacturing facility.

kWh_Base = 5,200 x 5 x 1.0 = 26000 kWh

kWh_EE = 5,200 x 1.0 = 5200 kWh

Electric Energy Savings (kWh/yr) = 26,000 kWh - 5,200 kWh = 20,800 kWh

Electric Peak Demand Savings (kW) = 20,800 kWh x 0.9 / 5,200 = 3.6 peak kW

Deemed Input Tables:

Table 1: Annual Operating Hours by Building Type (Ref. 6)

Building Type	Annual Operating Hours
Office	4,439
Restaurant	3,673
Retail	4,719
Grocery/Supermarket	5,802
Warehouse	4,746
Elementary School	2,422
Secondary School	4,311
College	3,540
Health	5,095
Hospital	6,038
Hotel/Motel	3,044
Manufacturing	5,200
Other/Misc.	4,576
24-Hour Facility	8,766

Table 2: Incremental cost of HVLS Fans by Size (Ref. 2)

HVLS Fan Size (Diameter, feet)	Incremental Cost
20 feet	$4,150
22 feet	$4,180
24 feet	$4,225

Notes:

There are currently no Federal energy efficiency standards in place for high velocity low speed fans.

References:

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, October 10, 2008. EUL value for this measure was assumed to be the same as HVAC Fan Motors.

2. ActOnEnergy, Program Year Three Technical Reference Manual No. 2010-4. Costs are based on the comparison of the prices of seven small (48" diameter) industrial low-speed fans and one HVLS fan. Average costs from three different manufacturers were analyzed.

3. D.W. Kammel, M.E, Raabe, J. J. Kappelman: Design of High Volume Low Speed Fan Supplemental Cooling System in Dairy Free Stall Barns

4. Manufacturer data from Rite Hite, Macro-Air, Big Ass Fans, and laboratory testing data for 48" fans from BESS labs showed that the difference in average input wattage for HVLS and standard fans is negligible. Average input wattage was shown to be around 1.0 kW. (http://bess.illinois.edu/) last accessed 08/31/12

5. 0.9 is a typical value used for central HVAC equipment in many programs. The range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.

6. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 pg 139. The Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, Ameren Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010.

Documentation Revision History

Version / Description	Author	Date
1)Original document	FES	8/1/2012
1.1) Changed name, minor revisions, removed Qty_HVLS (algorithm standard outputs are impacts per unit)	JP	2/11/2013

C/I HVAC - Unitary and Split Systems

Version No. 1.5

Measure Overview

Description:

This measure includes installation of electric DX packaged, split, and condensing units; and PTACs in replacement and new construction applications.

This measure analyzes the cooling savings potential of the installation of higher efficiency air-conditioning equipment.

This measure is applicable to DX cooling only, DX cooling and electric heat, and DX cooling and gas heat units.

The incremental cost is associated with base equipment cost and does not include any installation costs.

Actions: Replace on Fail, Replace Working or New Construction.
Target Market Segments: Commercial & Industrial
Target End Uses: HVAC

Applicable to: Commercial & Industrial customers where dx unitary equipment can be installed.

Algorithms

Unit kWh Savings per Year = Size x (12/SEER_base - 12/SEER_EE) x (EFLH_cool)

Unit Peak kW Savings = Size x (12/EER_base - 12/EER_EE) x CF

Unit Dth Savings per Year =0

Unit Gallons Fuel Oil Savings per Year =0

Unit Gallons Propane Savings per Year =0

Measure Lifetime (years) = 20 years (ref 1)

Unit Participant Incremental Cost = See Table 2

Where:

Size = Nominal cooling capacity in tons of the new equipment (1 ton = 12,000 btu/h)

SEER_base = Seasonal energy efficiency ratio of the baseline equipment, based on federal manufacturing requirements. See Table 2 for DX Packaged, Split and Condensing Units; for PTAC units, SEER_base = EER_base/0.875.

SEER_EE = Seasonal energy efficiency ratio of the high efficiency equipment, provided by the customer/contractor. If unknown, use SEER = EER / 0.875 (ref. 2)

EFLH_cool = Effective full load cooling hours based on the building type. See Table 1.

EER_base = Energy efficiency ratio of the baseline equipment, based on federal manufacturing requirements. See Table 2 for DX packaged, split, and condensing units; see Table 3 for PTAC units.

EER_EE = Energy efficiency ratio of the high efficiency equipment, provided by the customer/contractor. If unknown, use EER = .875 x SEER (ref. 2)

CF = Deemed coincidence factor, equal to 0.9 (ref. 3)

Required from Customer/Contractor: New equipment type, new equipment nominal cooling capacity in tons, new equipment EER/SEER, building type (refer to Table 1), project location (county)

Example 1:

Retrofit packaged rooftop installed in Medical Clinic, 7.5 ton cooling capacity, SEER 14, Climate Zone 3.

*Unit kWh Savings per Year = 7.5 * (12 / 12.6 - 12 / 14) * 865 = 618 KWh*

*Unit Peak kW Savings per Year = 7.5 * (12 /11 - 12 / 12.25) * 0.9 = 0.751 KW*

Example 2:

Replacement PTAC unit installed in motel, 9,000 Btu/hr cooling capacity, EER 13.0, Climate Zone 2.

*EER_base = 10.9 - (0.213 * 9,000/1,000) = 9.0*

SEER_base = 9.0 / 0.875 = 10.3

SEER_EE = 13 / 0.875 = 14.9

*Unit kWh Savings per Year = 9,000/12,000 * (12/10.3 – 12/14.9) * 606 = 163.4 kWh*

*Unit Peak kW Savings per Year = 9,000/12,000 * (12/9.0 – 12/13.0) * 0.9 = 0.277 kW*

Deemed Input Tables:

Table 1: Equivalent Full Load Hours of cooling per zone in Minnesota by building type (ref. 4)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	647	825	986
Education - Community College/University	682	782	785
Education - Primary	289	338	408
Education - Secondary	484	473	563
Health/Medical - Clinic	558	738	865
Health/Medical - Hospital	663	1089	1298
Lodging	401	606	754
Manufacturing	347	472	589
Office-Low Rise	257	359	446
Office-Mid Rise	373	529	651
Office-High Rise	669	1061	1263
Restaurant	347	535	652
Retail - Large Department Store	462	588	686
Retail - Strip Mall	307	441	574
Warehouse	164	343	409

Table 2: Deemed baseline efficiency and incremental costs for DX Packaged, Split, and Condensing Units (ref. 5, 6, 7)

Equipment	SEER_base*	EER_base*	Incremental Cost
DX Condensing Units > 11.3 tons	11.5/12.0	10.1/10.5	$100/ton
DX Packaged and Split Units <= 5.4 tons	13.0	11.4	$165/ton
DX Packaged and Split Units 5.5-11.3 tons	12.6	11.0	$150/ton
DX Packaged and Split Units 11.4-19.9 tons	12.3	10.8	$140/ton
DX Packaged and Split Units 20-63.3 tons	11.2	9.8	$125/ton
DX Packaged and Split Units > 63.3 tons	10.3/10.9	9.0/9.5	$110/ton

*Where two numbers are shown, first number represents ASHRAE 90.1-2004 min. efficiency, second number represents ASHRAE 90.1-2010 min. efficiency. The 2010 figures are shown because Minnesota may adopt ASHRAE 90.1-2010 for the Commercial Energy Code in 2014. The ASHRAE 90.1-2004 minimum efficiencies will be in effect for program year 2014.

Table 3: Deemed baseline efficiency and incremental costs for PTAC Units (Ref. 5, 7)

Equipment	Cooling Capacity (Btu/h)	EER_base	Incre-mental Cost
PTAC, Standard Size (used for New Construction)	< 7,000	11.7	$250/ton
	7,000-15,000	13.8 - (0.300 * Cap/1000)	$250/ton
	> 15,000	9.3	$250/ton
PTAC, Non-Standard Size (used for Replacements* only)	< 7,000	9.4	$250/ton
	7,000-15,000	10.9 - (0.213 * Cap/1000)	$250/ton
	> 15,000	7.7	$250/ton

*Replacement unit shall be factory labeled as follows "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS", Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406mm) in height and less than 42 inches (1067 mm) in width.

Methodology and Assumptions:

EFLH_Cool data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Assumed ventilation rates complied with the requirements of ASHRAE standard 62.1 - 2004.

Notes:

The equipment table was expanded to cover the intent of ASHRAE standard 90.1 - 2004.

The base line efficiencies are determined by federal manufacturing requirements. These efficiencies exceed the requirements of the Minnesota State Energy Codes.

ASHRAE 90.1-2010 requirements for PTAC units are the same as the current federal manufacturing requirements.

References:

1. ASHRAE Owning and Operating Equipment Data Base - Equipment Life/Maintenance Cost Survey

2. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment

3. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.

4. Calculated through energy modeling by FES 2012

5. Title 10, Code of Federal Regulations, Part 431 - Energy Efficiency Program for Certain Commercial and Industrial Equipment, Subpart F - Commercial Air Conditioners and Heat Pumps. January 1, 2010.

6. Xcel MN Workpapers 2010

7. Based on a review of TRM incremental cost assumptions from Vermont, Wisconsin, and California. This assumes that baseline shift from IECC 2006 to IECC 2009 carries the same incremental costs.

Documentation Revision History:

Version	Description	Author	Date
1	New deemed savings specification replacing Rooftop Units, Split Systems, Condensing Units, and PTAC sheets	JP	
1.1	Updated to specify SEER to EER conversion and EER to SEER conversion	JP	
1.2	Corrected algorithm to specify 12/EER instead of 1/EER, name changed from UnitarySystems to CommercialUnitarySystems	JP	
1.3	Corrected 'Eqiuvalent' to 'Equivalent' for Table 1 heading	SK	
1.3	Revised format to customer's current requirements. Updated to 2004 SEER to EER levels. Revised to hours in Table 1. Added references 3 thru 6. Updated references 1 &2. Revised PTAC cost/ton.	FES	
1.4	Added higher baseline efficiencies per ASHRAE 90.1-2010 in Table 2	JP	
1.5	Changed name from Commercial Unitary Systems to C/I HVAC - Unitary and Split Systems, updated baseline efficiency specifications for PTACs to reflect federal manufacturing requirements, updated description and example.	JP	3/29/14

C/I HVAC - Unitary Equipment Economizer

Version No. 1.2

Measure Overview

Description:

This measure includes the retro-fit of existing equipment or the optional addition of an air side economizer.

This measure analyzes the cooling savings potential of the installation of an air side economizer on unitary equipment.

This measure is applicable to dx and water cooled air systems.

Actions: Modify
Target Market Segments: Commercial & Industrial
Target End Uses: HVAC

Applicable to: Commercial & Industrial customers where air unitary equipment has been installed.

Algorithms

Unit kWh Savings per Year = Size x (12/SEER_EE) x EFLH_cool x SF x SM

Unit Peak kW Savings = 0

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 years (ref 1)

Unit Participant Incremental Cost = See Table 2 (ref 2)

Where:

Size = Nominal Cooling capacity in tons of the new equipment (1 ton = 12,000 btu/h)

EFLH_cool = Effective full load cooling hours based on the building type. See Table 1. (ref. 3)

SEER_EE = Energy efficiency ratio of the existing equipment, provided by the customer. If unknown, use SEER = EER/0.875 (ref. 4) Assume SEER = 10.9 if unavailable. (ref. 5)

SF = Deemed savings factor based upon zone. See Table 2. (ref. 6)

SM = Deemed System Multiplier. SM = 1 for Constant Air Volume (CAV) Systems and SM = 1.4 for Variable Air Volume (VAV) systems. (ref. 7)

Required from Customer/Contractor: Existing equipment type, existing equipment nominal cooling capacity in tons, existing equipment EER/SEER, building type (refer to Table 1), project location (county)

Example:

Install an economizer by retrofitting a packaged rooftop installed in a Health Care Clinic, 20 ton cooling capacity, SEER 14.4, VAV system, Climate Zone 1.

*Unit KWh Savings per Year = 20 * (12 / (14.4*0.875)) * 879 * 0.24 *1.4 = 5626 KWh*

Deemed Input Tables:

Table 1: Equivalent Full Load Hours of cooling per zone in Minnesota by building type (ref. 3)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	647	825	986
Education - Community College/University	682	782	785
Education - Primary	289	338	408
Education - Secondary	484	473	563
Health/Medical - Clinic	558	738	865
Health/Medical - Hospital	663	1089	1298
Lodging	401	606	754
Manufacturing	347	472	589
Office-Low Rise	257	359	446
Office-Mid Rise	373	529	651
Office-High Rise	669	1061	1263
Restaurant	347	535	652
Retail - Large Department Store	462	588	686
Retail - Strip Mall	307	441	574
Warehouse	164	343	409

Table 2: Deemed Savings Factor for Zone and incremental costs

Equipment	Savings Factor (ref. 6)			Incremental Cost** (ref. 2)
	Zone 1	Zone 2	Zone 3	
Units* less than or equal to 10 tons	0.240	0.130	0.100	$1,500
Units* 11-20 tons	0.240	0.130	0.100	$1,900
Units* 21-30 tons	0.240	0.130	0.100	$2,100
Units* 31-60 tons	0.240	0.130	0.100	$2,500
Units* 61-100 tons	0.240	0.130	0.100	$4,000

** Units include packaged and built up air-handler units.*

*** An additional $1000 should be included when retro-fitting existing units.*

Methodology and Assumptions:

EFLH_Cool data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Assumed ventilation rates complied with the requirements of ASHRAE standard 62.1 - 2004.

Methodoolgy assumes 30% savings for VAV over CV systems.

Incremental costs include controls and programming and assume similar cost between dx and water cooled equipment.

Savings assume economizer is given preference over demand control ventilation strategy.

Notes:

Current code requires incorporation of economizer on all dx equipment 5.4 tons and greater for all three Minnesota weather zones.

References:

1. "Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", by GDS Associates, Inc. June 2007, pg. 6

2. "Economizers for Packaged Air Systems" , Energy Efficiency Office, Department of Natural Resources, Canada

3. Calculated through energy modeling by FES 2012

4. "ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment"

5. "Small Commercial HVAC, Surveying the Frontier of Energy Efficiency", by Lee DeBallie, PE - Energy Center of Wisconsin

6. Calculated through energy modeling by FES 2012

7. Calculated from the inverse of 0.7. Typical energy consumption of VAV systems are 70% of CV systems. Multiplier verified through energy modeling by FES 2012 and modeling results verified by "Energy Cost and IAQ Performance of Ventilation Systems and Controls - Project Report#2: Assessment of CV and VAV Ventilation Systems and Outdoor Air Control Strategies", pg. 7, by Indoor Environmental Division, EPA, January 2000

Documentation Revision History:

Version	Description	Author	Date
1	New savings specification for retrofit/incorporation of air economizer on air systems.	FES	
1.1	Minor edits	JP	
1.2	Changed Action Type from Replace Working to Modify	JP	6/6/2014

C/I HVAC - Variable Speed Drives

Version No. 1.2

Measure Overview

Description:

This measure applies to variable speed drives installed on HVAC systems including;

- HVAC Fans - supply fans, return fans, and cooling tower fans
- HVAC Pumps - hot water heating and chilled water cooling pumps

The VSD will vary the speed of the motor in a HVAC application with a diversified load.

In the applicable HVAC applications the power of the motor is approximately proportional to the cube of the speed, providing significant energy savings.

Actions: Modify, Replace Working (Retrofit), New Construction (limited sizes, see Notes)
Target Market Segments: Commercial, Industrial
Target End Uses: HVAC

Applicable to: Commercial and Industrial for space heating and cooling applications.

Algorithms

Unit kWh Savings per Year = HP x LF x Conversion / Eff x Hrs x ESF

Unit Peak kW Savings = 0

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 (Ref. 1)

Unit Participant Incremental Cost: See Table 4 (Ref.2)

Where:

HP = Rated horsepower of new drive, assumed to be the same as associated motor.

LF = Motor load factor = 75%. (Ref. 3)

Conversion = .746 (1 HP = .746 kW)

Eff = Efficiency of motor, if unknown see default values by size in Table 2 (Ref. 5)

Hrs = Annual operating hours, if unknown see default values by application in Table 1 (Ref.4)

ESF = Energy Savings Factor per Table 3 (Ref. 6,7)

Required from Customer/Contractor: Horsepower, application type (see Table 1), application (see Table 3), motor efficiency (optional), annual operating hours (optional).

Example:

For 20 hp chilled water pump retrofitted with an variable speed drive:

Unit kWh Savings per Year = 20 x 0.75 x 0.746 / 0.92 x 2,170 x 0.432 = 11,402 kWh

Deemed Input Tables:

Table 1: Deemed annual operating hours by application type (Ref. 4)

Application Type	Annual Operating Hours
Chilled Water Pump	2,170
Heating Hot Water Pump	4,959
Condenser Water Pump	2,170
HVAC Fan	5,236
Cooling Tower Fan	1,032

Table 2: Motor Efficiency (Ref. 5)

Horsepower (HP)	Motor Efficiency
5	0.87
7.5	0.88
10	0.90
15	0.90
20	0.91
25	0.91
30	0.92
40	0.92
50	0.93
60	0.93
75	0.93
100	0.93

Table 3: Energy Savings Factor (Ref. 6, 7)

Application	ESF
HVAC Pumps	
Hot Water Pump	0.482
Chilled Water or Condenser Water Pump	0.432
HVAC Fans, Supply or Return	
Constant Volume (no flow control)	0.535
Air Foil/inlet Guide Vanes	0.227
Forward Curved Fan, with discharge dampers	0.179
Forward Curved Inlet Guide Vanes	0.092
Fan Average (unknown type)	0.258
Cooling Tower Fan	0.249

Table 4: HVAC VSD Incremental Costs, Including equipment and installation costs (Ref. 2)

Horsepower (HP)	Fan	Pump
5	$1,840	$3,420
7.5	$2,620	$4,200
10	$2,640	$4,300
15	$2,740	$4,600
20	$3,520	$5,460
25	$4,540	$6,580
30	$4,840	$7,340
40	$4,960	$7,540
50	$6,780	$9,160
60	$10,260	$13,360
75	$12,380	$15,460
100	$15,340	$18,580

Methodology and Assumptions:

Demand savings are assumed to be minimal, as it is assumed that demand savings for HVAC measures are defined as summer peak hour savings.

Savings are calculated based upon a constant speed baseline operation.

Variable speed does not include multi-speed (two or three speed) applications.

Costs do not include motor replacement cost.

Assumes existing motor is VFD compatible.

Savings and costs are based upon single motor application and do not consider series or parallel applications.

Notes:

Speed or capacity control is required by energy code by size and application; for ASHRAE 90.1-2007 50hp and larger for pumps, 10hp and larger for supply/return fans, and 7.5hp and larger for cooling towers.

Speed or capacity control is required by energy code by size and application; for ASHRAE 90.1-2010 5hp and larger for pumps, 5hp and larger for supply fans, 10hp or larger for return fans and 7.5hp and larger for cooling towers.

It is generally accepted that VSDs provide this capacity control for these sizes, and should be considered the baseline for New Construction

Operation below 30% of design speed is not recommended.

References:

1. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008

2. CL&P and UI Program Savings Documentation for 2008 Program Year, total installation cost is double material cost, this includes labor and additional items such as sensors other required modifications

3. United States Industrial Electric Motor Systems Market Opportunities Assessment, EERE, US DOE, Dec 2002 - Source for motor load factor data

4. Pennsylvania Technical Reference Manual, June 2011, average of hours by application across all building types

5. Average of Premium Efficiency Motor specification abd EPAct Motor specification averaged over all types and speeds, by horsepower

6. CL&P and UI Program Savings Documentation for 2008 Program Year, savings factor based on bin spreadsheet calculation, all applications except cooling tower fans

7. Cooling tower savings factor, Pennsylvania Technical Reference Manual, June 2011, savings based on building simulation

Documentation Revision History:

Version/Description	Author	Date
1) New Measure	FES	8/1/2012
1.1) Minor revisions	JP	2/12/2013
1.2) Added annual operating hours as an optional input from customer/contractor, clarified Required Inputs	JP	1/6/2014

C/I Lighting - CFL Standard to Low Wattage Retrofit

Version No. 3.4

Measure Overview

Description: This measure replaces standard wattage plug-in CFL lamps with lower wattage plug-in CFL lamps, nominally 40 watt lamps replaced by 28 watt or 25 watt lamps. These lamps plug into the fixture and can be used with the existing ballast and base. Commonly referred to as Dulux, Biax, or PL lamps.

Actions: Replace Working, Replace on Fail
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x (kW_Base - kW_EE) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 8000 / Hrs (Ref. 1)

Unit Participant Incremental Cost: see Appendix B

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = High Efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = Deemed annual operating hours from Table 2 based on building type

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: Existing fixtures and quantities (retrofits only), installed fixtures and quantities, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned)

Example:

Replace (1) PL 40W CFL with (1) PL 25W CFL in an office space.

*kWh Savings = (0.040-0.025)*4,439*1.095 = 72.91 kWh*

kW Savings = 0.7(0.040-0.025)*1.254 = 0.013 kW*

*Heating Penalty = (0.040-0.025)*4,439*-0.0023 = -0.153 Dth/year*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System (Ref. 2)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Lighting Measures	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only or Heating & Cooling
All Except Exterior/ Unconditioned	1.00	1.254	1.00	1.095	-0.0023
Exterior/ Unconditioned Space	1.00	1.00	1.00	1.00	0

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 3) and Annual Operating Hours by Building Type (Ref. 4)

Building Type	CF	Hrs
Office	70%	4,439
Restaurant	80%	3,673
Retail	83%	4,719
Grocery/Supermarket	90%	5,802
Warehouse	70%	4,746
Elementary School	71%	2,422
Secondary School	58%	4,311
College	81%	3,540
Health	75%	5,095
Hospital	75%	6,038
Hotel/Motel	21%	3,044
Manufacturing	92%	5,200
Other/Misc.	66%	4,576
24-Hour Facility	100%	8,766
Safety or Code Required	100%	8,766
Exterior lighting	0%	4,903

Methodology and Assumptions:

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes (see http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf), and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

References:

1. Product life assumption of 8,000 hours determined through survey of on-line retailers, July 2012

2. Calculated through energy modeling be FES 2012

3. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version

4. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010

5. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

Document Revision History:

Version / Description	Author	Date
1) Lighting calculator from Xcel Energy with rebate calculation deleted and extraneous tabs hidden	Xcel Energy	
2) Incorporated most recent product pairings from Xcel; eliminated calculator; split controls off into a separate spreadsheet, general clean-up to remove Xcel-specific items. Changed 24-hr facility hours to 8700.	JP	
2.1) Corrected some nomenclature issues and eliminated superfluous pairings from the New Construction table. Revised measure lifetimes to equal rated lifetime in hours of new lighting product (supplied by vendor) divided by deemed annual operating hours	JP	
2.2) Corrected some nomenclature issues that were missed.	JP	
2.3) Updated lifetime to use 20 years for fixtures and rated lifetime/annual operating hours for lamps	JP	
2.4) Updated lifetime to clarify to use 20 years for new construction	JP	
2.5) Updated Table 1 (HVAC interactive factors) to account for exterior lighting and fridge/freezer lighting	JP	
2.6) Added provision for Hrs such that Exit Signs always uses 8,760 hours regardless of building type	JP	
3) New format, updated measure life, updated hours, updated CFs, updated resources, updated measure name, reviewed incremental costs and all appear in line with online surveys, manufacturer data, and cost studies	FES	8/31/2012
3.1) Changed measure life from deemed figure of 1.81 years to formula based on annual operating hours, minor revisions	JP	2/6/2013
3.2) Changed Table 3 references to Appendix B	JP	11/24/13
3.3) Removed rated product lifetime in hours from required inputs, changed “exterior” to “exterior/unconditioned space” in HVAC table	JP	3/4/14
3.4) Changed grocery store CF from 69% to 90% to reflect 2011 DEER update (see *DEER Database: 2011 Update Documentation,* Itron, Inc., November 8, 2011), added reference for product life assumption	JP	7/9/14

C/I Lighting - Controls

Version No. 3.4

Measure Overview

Description:

Occupancy sensors represent an energy-efficient way to control lighting use in low occupancy areas such as halls, storage rooms, and restrooms. Instead of relying on people to remember to switch lights off when they leave a space, occupancy sensors perform this task. They measure the movement of people within a space. When movement is detected, the lights turn on automatically; they then shut off when they no longer sense movement. Each unit's shut-off time can be preset, given the needs of the space being controlled.

Systems use daylight sensor lighting controls to take advantage of available daylight in perimeter building spaces (open spaces within 10' to 15' of windows) or other areas that have access to daylight infiltration. Daylight sensor lighting controls can be used to turn lights on or off, stepped dimming (high/low or inboard/outboard), or continuous dimming based on light levels from available daylight. Especially useful in common spaces where task lighting is not critical (malls, warehouses, atriums, etc.)

Actions: Modify, New Construction
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

Algorithms

Unit kWh Savings per Year = kW_connected x (1-PAF) x Hrs xHVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x kW_connected x(1-PAF)x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = kW_connected x (1-PAF) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil/Propane Savings per Year = 0

Measure Lifetime (years) = 8 years (Ref. 1)

Unit Participant Incremental Cost: See Table 3

Where:

kW_connected = Total connected fixture load, determined as the sum of stipulated fixture wattages from the Retrofit or New Construction Tables in the C/I Lighting Measure.

Hrs = Deemed annual operating hours from Table 2 based on building type.

PAF = Deemed Power Adjustment Factor per Table 3.

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from lighting control from Table 1.

Required from Customer/Contractor: Control type/quantity, connected load (kW) to each control, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned)

Example:

Install a wall mounted occupancy sensor with a connected load of 0.560 kW (10 - 2L 32W T8 fixtures) in an office space.

*kWh = 0.560kW * (1-0.70) * 4,439 * 1.095 = 816.6 kWh*

*kW = 0.7 * 0.560 * (1-0.70) * 1.254 = 0.15 kW*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System (Ref. 2)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Lighting Measures	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only or Heating & Cooling**
All Except Exterior/ Unconditioned	1.00	1.254	1.00	1.095	-0.0023
Exterior/ Unconditioned Space	1.00	1.00	1.00	1.00	0

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 3) and Annual Operating Hours by Building Type (Ref. 4)

Building Type	CF	Hrs
Office	70%	4,439
Restaurant	80%	3,673
Retail	83%	4,719
Grocery/Supermarket	90%	5,802
Warehouse	70%	4,746
Elementary School	71%	2,422
Secondary School	58%	4,311
College	81%	3,540
Health	75%	5,095
Hospital	75%	6,038
Hotel/Motel	21%	3,044
Manufacturing	92%	5,200
Other/Misc.	66%	4,576
24-Hour Facility	100%	8,766
Safety or Code Required	100%	8,766
Exterior lighting	0%	4,903

Table 3: Deemed Power Adjustment Factors (Ref. 1) and Incremental Costs (Ref. 4)

Control Type	PAF	Incremental Cost
Occupancy Sensor - Wall Mount	0.700	$55
Occupancy Sensor - Ceiling Mount	0.700	$125
Daylighting - Continuous Dimming	0.567	$65
Daylighting - Multiple Step Dimming	0.648	$65
Daylighting - On/Off	0.729	$65

Methodology and Assumptions:

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Notes:

Adoption of ASHRAE Standard 90.1-2007 or 90.1-2010 will require occupancy sensors in many spaces for new construction.

References:

1. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08
2. Calculated through energy modeling be FES 2012
3. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version
4. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010
5. Xcel Energy 2010-2012 CIP Triennial Plan, pp. 525-547 (Docket No. E,G002/CIP-09-198)

Document Revision History:

Version / Description	Author	Date
1)Standalone spreadsheet incorporating controls portion of CommercalLighting_v01.xls	JP	
2)Added incremental costs, changed name from CommercialLightingControls to CI_LightingControls	JP	
2.1) Updated Table 1 (HVAC interactive factors) to account for exterior lighting and fridge/freezer lighting	JP	
3) Updated format, CFs, Ifs, Hours, Sources, and measure life.	FES	8/31/2012
3.1) Minor revisions, eliminated Ref 5	JP	2/6/2013
3.2) Changed action types to Modify, New Construction	JP	11/22/2013
3.3) Changed “exterior” to “exterior/unconditioned space” in HVAC table	JP	5/8/14
3.4) Changed grocery store CF from 69% to 90% to reflect 2011 DEER update (see *DEER Database: 2011 Update Documentation,* Itron, Inc., November 8, 2011)	JP	7/9/14

C/I Lighting - Exit Sign Retrofit with LED/LEC

Version No. 3.3

Measure Overview

Description: This measure evaluates the retrofit and replacement of incandescent or compact fluorescent exit signs with energy efficient LED and LEC exit signs. ENERGY STAR labeled exit signs operate on five watts or less per sign, compared to the standard signs, which use as much as 40 watts per sign. Existing fixtures may be incandescent or compact fluorescent.

Actions: Replace Working, Replace on Fail
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x (kW_Base - kW_EE) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 16 years (Ref. 1)

Unit Participant Incremental Cost: See Appendix B

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = High Efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = Deemed annual operating hours = 8,766; all exit signs operate 24 hours/day

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF = 100%

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: Existing fixtures and quantities (retrofits only), installed fixtures and quantities, HVAC system (heating only, heating & cooling, unconditioned)

Example:

Replace a 40W incandescent exit sign with a 2W LED exit sign in an office space.

*kWh Savings = (0.040-0.002)*8,766*1.095 = 364.75 kWh*

kW Savings = 1.0(0.040-0.002)*1.254 = 0.0477 kW*

*Heating Penalty = (0.040-0.002)*8,766*-0.0023 = -0.766 Dth/year*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System (Ref. 2)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Lighting Measures	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only or Heating & Cooling**
All Except Exterior/Uncond.	1.00	1.254	1.00	1.095	-0.0023
Exterior/ Unconditioned Space	1.00	1.00	1.00	1.00	0

Methodology and Assumptions:

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Notes:

EPA suspended the ENERGY STAR Exit Sign specification effective May 1, 2008. In EPAct 2005, Congress passed a new minimum federal efficiency standard for electrically-powered, single-faced exit signs with integral light sources that are equivalent to ENERGY STAR levels for input power demand. EPAct 2005 references the ENERGY STAR Version 2.0 specification. All exit signs manufactured on or after January 1, 2006 must have an input power demand of 5 watts or less per face.

References:

1. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08

2. Calculated through energy modeling be FES 2012

5. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

6. NYSERDA Deemed Savings Database, Labor cost assumes 25 minutes @ $18/hr taken from the State of Illinois Technical Reference Manual 2012 and 2012 manufacturer product survey and project data.

Document Revision History:

Version / Description	Author	Date
1) Lighting calculator from Xcel Energy with rebate calculation deleted and extraneous tabs hidden	Xcel Energy	
2) Incorporated most recent product pairings from Xcel; eliminated calculator; split controls off into a separate spreadsheet, general clean-up to remove Xcel-specific items. Changed 24-hr facility hours to 8700.	JP	
2.1) Corrected some nomenclature issues and eliminated superfluous pairings from the New Construction table. Revised measure lifetimes to equal rated lifetime in hours of new lighting product (supplied by vendor) divided by deemed annual operating hours	JP	
2.2) Corrected some nomenclature issues that were missed.	JP	
2.3) Updated lifetime to use 20 years for fixtures and rated lifetime/annual operating hours for lamps	JP	
2.4) Updated lifetime to clarify to use 20 years for new construction	JP	
2.5) Updated Table 1 (HVAC interactive factors) to account for exterior lighting and fridge/freezer lighting	JP	
2.6) Added provision for Hrs such that Exit Signs always uses 8,760 hours regardless of building type	JP	
3) New format, updated measure life, updated hours, updated CFs, updated resources, updated measure name, reviewed incremental costs and all appear in line with online surveys, manufacturer data, and cost studies	FES	8/17/2012
3.1) Minor revisions	JP	2/6/2013
3.2) Changed Table 2 references to Table 3	JP	11/24/13
3.3) Changed “exterior” to “exterior/unconditioned space” in HVAC table	JP	5/8/14

C/I Lighting - Exterior Canopy/Soffit Retrofit with LEDs

Version No. 3.3

Measure Overview

Description: Exterior high pressure sodium, metal halide, mercury vapor, and pulse start metal halide fixtures can all be replaced with energy efficient LED exterior light fixtures in canopy and soffit applications. Utilizing LED lighting, a large energy savings can be accomplished without a great lumen reduction in the area.

Actions: Replace working, Replace on Fail
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Exterior canopy/soffit lighting at any facility type

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs

Unit Peak kW Savings = CF x (kW_Base - kW_EE)

Unit Natural Gas Savings (Dth/yr) = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 50,000 / Hrs (Ref. 1)

Unit Participant Incremental Cost: See Appendix B

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = High Efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = Deemed annual operating hours from Table 1 based on building type

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided exterior lighting type in table 1.

Required from Customer/Contractor: Existing fixtures and quantities, installed fixtures and quantities, exterior lighting type (24/7 or nighttime)

Example:

Replace (1)100W area HPS fixture with (1) 25W area LED fixture in a parking lot.
*kWh Savings = (0.130-0.025)*4,903*1.0 = 514.82 kWh*
kW Savings = 0(0.130-0.025)*1.0 = 0 kW*
*Heating Penalty = (0.130-0.025)*4,903*0 = 0 Dth/year*

Deemed Input Tables:

Table 1: Deemed Peak Demand Coincidence Factors (Ref. 3) and Annual Operating Hours by Exterior Lighting Type (Ref. 4)

Exterior Lighting Type	CF	Hrs
24-hr, safety or code required	100%	8,766
Nighttime lighting	0%	4,903

Methodology and Assumptions:

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

References:

1. Product life assumption of 50,000 hours from Illinois Technical Reference Manual, July 2012, confirmed with survey of online retailers, July 2012

2. Calculated through energy modeling be FES 2012

3. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version

4. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010

5. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

Document Revision History:

Version / Description	Author	Date
1) Lighting calculator from Xcel Energy with rebate calculation deleted and extraneous tabs hidden	Xcel Energy	
2) Incorporated most recent product pairings from Xcel; eliminated calculator; split controls off into a separate spreadsheet, general clean-up to remove Xcel-specific items. Changed 24-hr facility hours to 8700.	JP	

2.1) Corrected some nomenclature issues and eliminated superfluous pairings from the New Construction table. Revised measure lifetimes to equal rated lifetime in hours of new lighting product (supplied by vendor) divided by deemed annual operating hours	JP	
2.2) Corrected some nomenclature issues that were missed.	JP	
2.3) Updated lifetime to use 20 years for fixtures and rated lifetime/annual operating hours for lamps	JP	
2.4) Updated lifetime to clarify to use 20 years for new construction	JP	
2.5) Updated Table 1 (HVAC interactive factors) to account for exterior lighting and fridge/freezer lighting	JP	
2.6) Added provision for Hrs such that Exit Signs always uses 8,760 hours regardless of building type	JP	
3) New format, updated measure life, updated hours, updated CFs, updated resources, updated measure name, reviewed incremental costs and all appear in line with online surveys, manufacturer data, and cost studies. Added LED area and wall pack options. Changed measure name from "Exterior Canopy Retrofit" to "Exterior Retrofit" to encompass new measures	FES	8/31/2012
3.1) Removed HVAC interactive variables from algorithms, changed measure lifetime from deemed figure to formula based on annual operating hours, removed Table 1 (HVAC interactive factors), consolidated Table 2 and changed 'building type' to 'exterior lighting type'	JP	2/6/2013
3.2) Changed Table 2/3 references to Appendix B	JP	11/24/13
3.3) Added reference for product life assumption	JP	7/9/14

C/I Lighting - Exterior Wall Pack Retrofit with LEDs

Version No. 1.0

Measure Overview

Description: Exterior high pressure sodium, metal halide, mercury vapor, and pulse start metal halide fixtures can all be replaced with energy efficient LED exterior wall pack fixtures. Utilizing LED lighting, a large energy savings can be accomplished without a great lumen reduction in the area.

Actions: Replace working, Replace on Fail
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Exterior wall pack lighting at any facility type including parking garages

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs

Unit Peak kW Savings = CF x (kW_Base - kW_EE)

Unit Natural Gas Savings (Dth/yr) = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 50,000 / Hrs (Ref. 1)

Unit Participant Incremental Cost: See Appendix B

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = High Efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = Deemed annual operating hours from Table 1 based on building type

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided exterior lighting type in table 1.

Required from Customer/Contractor: Existing fixtures and quantities, installed fixtures and quantities, exterior lighting type (24/7 or nighttime)

Example:

Replace (1)100W area HPS fixture with (1) 25W area LED fixture in a parking lot.
*kWh Savings = (0.130-0.025)*4,903*1.0 = 514.82 kWh*
kW Savings = 0(0.130-0.025)*1.0 = 0 kW*
*Heating Penalty = (0.130-0.025)*4,903*0 = 0 Dth/year*

Deemed Input Tables:

Table 1: Deemed Peak Demand Coincidence Factors (Ref. 3) and Annual Operating Hours by Exterior Lighting Type (Ref. 4)

Exterior Lighting Type	CF	Hrs
24-hr, safety or code required	100%	8,766
Nighttime lighting	0%	4,903

Methodology and Assumptions:

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

References:

1. Product life assumption of 50,000 hours from Illinois Technical Reference Manual, July 2012, confirmed with survey of online retailers, July 2012

2. Calculated through energy modeling be FES 2012

3. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version

4. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010

5. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

Document Revision History:

Version / Description	Author	Date
1) New measure derived from previous Exterior Canopy Retrofit measure.	JP	2.18.14

C/I Lighting - High Pressure Sodium Retrofit

Version No. 3.3

Measure Overview

Description:

This measure evaluates high pressure sodium fixtures replaced by pulse start metal halides, high bay fluorescent fixtures, parking garage fluorescent, and ceramic metal halides.
Pulse start metal halide systems typically consume 20 percent less energy than high pressure sodium systems, produce the same light at lower wattages, and can often use more efficient ballasts depending on the application.

High bay fluorescent systems are often utilized in high bay ceiling applications over 15 feet. High bay fluorescent and parking garage fluorescent systems offer lower depreciation rates, better dimming options, virtually instant start-up and re-strike, better color rendition, and reduced glare.

Ceramic metal halides can be utilized to replace high pressure sodium in lower wattage applications and result in better color rendition, lower wattage consumption, and improved color temperature.

Actions: Replace on fail, replace working
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buidlings

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE)xHrs xHVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x (kW_Base - kW_EE)xHVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = Ceramic Metal Halide 13 years (Ref. 1), High Bay Fluorescent 15 years (Ref. 2), Parking Garage Fluorescent 15 years (Ref. 2) Pulse Start Metal Halide 15 years (Ref. 3)

Unit Participant Incremental Cost : See Appendix B

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = High Efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = Deemed annual operating hours from Table 2 based on building type.

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: Existing fixtures and quantities (retrofits only), installed fixtures and quantities, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned)

Example:

Replace a 250W High Pressure Sodium fixture with a 2 Lamp F54T5HO fixture in a warehouse.

*kWh Savings = (0.295-0.117)*4,746*1.095 = 925.04 kWh*

kW Savings = 0.70(0.295-.117)*1.254 = 0.156 kW*

*Heating Penalty = (0.295-0.117)*4,746*-0.0023 = -1.94 Dth/year*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System (Ref. 4)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Lighting Measures	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only or Heating & Cooling**
All Except Exterior/Uncond.	1.00	1.254	1.00	1.095	-0.0023
Exterior/Uncond. Space	1.00	1.00	1.00	1.00	0

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 5) and Annual Operating Hours by Building Type (Ref. 6)

Building Type	CF	Hrs
Office	70%	4,439
Restaurant	80%	3,673
Retail	83%	4,719
Grocery/Supermarket	90%	5,802
Warehouse	70%	4,746
Elementary School	71%	2,422
Secondary School	58%	4,311
College	81%	3,540
Health	75%	5,095
Hospital	75%	6,038
Hotel/Motel	21%	3,044
Manufacturing	92%	5,200
Other/Misc.	66%	4,576
24-Hour Facility	100%	8,766
Safety or Code Required	100%	8,766
Exterior lighting	0%	4,903

Methodology and Assumptions:

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Notes:

New construction wattage tables are available in the CI Lighting New Construction file.

The Energy Independence and Security Act of 2007 legislation sets standards for ballasts used in new metal halide luminaires that operate lamps from 150 to 500 watts. New metal halide luminaires must contain ballasts that meet new efficiency standards. Pulse-start metal halide ballasts must have a minimum ballast efficiency of 88%, magnetic probe-start ballast a minimum efficiency of 94%. New metal halides operating lamps of 150-500 watts manufactured on or after January 1, 2009 contain pulse-start, magnetic or electronic, metal halide ballasts with a minimum efficiency of 88%.

References:

1. State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation *Business Programs: Measure Life Study* Final Report: August 25, 2009

2. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08 (range from 13-16 years, 15 years was selected)

3. Residential and Commercial/Industrial Lighting and HVAC Measures for use as Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM) June 2007 GDS Associates, Inc.

4. Calculated through energy modeling be FES 2012

5. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version

6. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 pg 218. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010

7. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

Document Revision History:

Version / Description	Author	Date
1) Lighting calculator from Xcel Energy with rebate calculation deleted and extraneous tabs hidden	Xcel Energy	
2) Incorporated most recent product pairings from Xcel; eliminated calculator; split controls off into a separate spreadsheet, general clean-up to remove Xcel-specific items. Changed 24-hr facility hours to 8700.	JP	
2.1) Corrected some nomenclature issues and eliminated superfluous pairings from the New Construction table. Revised measure lifetimes to equal rated lifetime in hours of new lighting product (supplied by vendor) divided by deemed annual operating hours	JP	
2.2) Corrected some nomenclature issues that were missed.	JP	
2.3) Updated lifetime to use 20 years for fixtures and rated lifetime/annual operating hours for lamps	JP	
2.4) Updated lifetime to clarify to use 20 years for new construction	JP	
2.5) Updated Table 1 (HVAC interactive factors) to account for exterior lighting and fridge/freezer lighting	JP	
2.6) Added provision for Hrs such that Exit Signs always uses 8,760 hours regardless of building type	JP	
3) New format, updated measure life, updated hours, updated CFs, updated resources, updated measure name, reviewed incremental costs and all appear in line with online surveys, manufacturer data, and cost studies	FES	8/17/2012
3.1) Changed table 2, 3 references to Appendix B	JP	11/24/13
3.2) Changed “exterior” to “exterior/unconditioned space” in HVAC table	JP	2/21/14
3.3) Changed grocery store CF from 69% to 90% to reflect 2011 DEER update (see *DEER Database: 2011 Update Documentation,* Itron, Inc., November 8, 2011)	JP	7/9/14

C/I Lighting - Incandescent Over 100W Retrofit

Version No. 3.4

Measure Overview

Description: This measure replaces Incandescent fixtures over 100 watts with various technologies including ceramic metal halides, high pressure sodium fixtures, integrated ballast ceramic metal halides, LED lamps, LED luminaire, pin-based CFL, pulse start metal halides, T5 fixtures, and T8 fixtures. The replacement fixture technology will depend on the specific application and environment.

Actions: Replace working, Retrofit
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x (kW_Base - kW_EE) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (yrs) = Measure life varies based on installed technology as shown in Table 3

Unit Participant Incremental Cost: See Appendix B

Where:

kW_Base = Baseline fixture wattage (kW per fixture) determined from Appendix B

kW_EE = High Efficiency fixture wattage (kW per fixture) determined from Appendix B

Hrs = Deemed annual operating hours from Table 2 based on building type

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be found based on customer provided building type in table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: Existing fixtures and quantities, installed fixtures and quantities, building type**,** HVAC system (heating only, heating & cooling, exterior/unconditioned)

Example:

Replace (1) 105W Incandescent fixture with (1) Ceramic Metal halide PAR 39 in an office space

*kWh Savings = (0.105-0.045)*4,439*1.095 = 291.64 kWh*

kW Savings = 0.7(0.105-0.045)*1.254 = 0.0527 kW*

*Heating Penalty = (0.105-0.045)*4,439*-0.0023 = -0.613 Dth/year*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System (Ref. 2)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Lighting Measures	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only or Heating & Cooling**
All Except Exterior/Uncond.	1.00	1.254	1.00	1.095	-0.0023
Exterior/Uncond. Space	1.00	1.00	1.00	1.00	0

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 3) and Annual Operating Hours by Building Type (Ref. 4)

Building Type	CF	Hrs
Office	70%	4,439
Restaurant	80%	3,673
Retail	83%	4,719
Grocery/Supermarket	90%	5,802
Warehouse	70%	4,746
Elementary School	71%	2,422
Secondary School	58%	4,311
College	81%	3,540
Health	75%	5,095
Hospital	75%	6,038
Hotel/Motel	21%	3,044
Manufacturing	92%	5,200
Other/Misc.	66%	4,576
24-Hour Facility	100%	8,766
Safety or Code Required	100%	8,766
Exterior lighting	0%	4,903

Table 3: Measure Life

Installed Technology	Measure Life	Reference
Ceramic Metal Halide	13	7
High Pressure Sodium	15	11
Integrated Ballast Ceramic Metal Halide	13	7
LED Lamps	7.9	8
LED Luminaire	7.9	9
Pin-Based CFL	2.3	10
Pulse Start Metal Halide	15	1
T5 fixtures	15	6
T8 fixtures	15	6

Methodology and Assumptions:

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

References:

1.Residential and Commercial/Industrial Lighting and HVAC Measures for use as Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM) June 2007 GDS Associates, Inc.

2. Calculated through energy modeling be FES 2012

3. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version

4. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010

5. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

6. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08 (range from 13-16 years, 15 years was selected)

7. State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report: August 25, 2009

8. LED lamp rated hours of 35,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 7.9 years for measure life

9. LED luminaire rated hours of 35,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 7.9 years for measure life

10. Pin-based CFL lamps rated hours of 10,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 2.3 years for measure life.

11. Xcel Energy uses 20 years in 2013-2015 Minnesota CIP Triennial Plan (Docket No. E,G002/CIP-12-447), per communication with Commerce staff. Fixture may be considered permanent once installed. However, life was decreased to 15 years for consistency with maximum lifetimes for other technologies.

Document Revision History:

Version / Description	Author	Date
1) Lighting calculator from Xcel Energy with rebate calculation deleted and extraneous tabs hidden	Xcel Energy	
2) Incorporated most recent product pairings from Xcel; eliminated calculator; split controls off into a separate spreadsheet, general clean-up to remove Xcel-specific items. Changed 24-hr facility hours to 8700.	JP	
2.1) Corrected some nomenclature issues and eliminated superfluous pairings from the New Construction table. Revised measure lifetimes to equal rated lifetime in hours of new lighting product (supplied by vendor) divided by deemed annual operating hours	JP	
2.2) Corrected some nomenclature issues that were missed.	JP	
2.3) Updated lifetime to use 20 years for fixtures and rated lifetime/annual operating hours for lamps	JP	
2.4) Updated lifetime to clarify to use 20 years for new construction	JP	
2.5) Updated Table 1 (HVAC interactive factors) to account for exterior lighting and fridge/freezer lighting	JP	
2.6) Added provision for Hrs such that Exit Signs always uses 8,760 hours regardless of building type	JP	
3) New format, updated measure life, updated hours, updated CFs, updated resources, updated measure name, reviewed incremental costs and all appear in line with online surveys, manufacturer data, and cost studies	FES	8/31/2012
3.1) Eliminated rated product lifetime as a required input, edited existing devices to make format consistent and remove bulb types which are not needed, minor revisions	JP	2/6/2013
3.2) Changed Table 4 references to Appendix B	JP	11/24/13
3.3) Added high pressure sodium replacement fixtures to reflect latest lighting table in Appendix B, changed "exterior" to "exterior/unconditioned space" in HVAC table	JP	2/21/14
3.4) Changed grocery store CF from 69% to 90% to reflect 2011 DEER update (see *DEER Database: 2011 Update Documentation,* Itron, Inc., November 8, 2011)	JP	7/9/14

C/I Lighting - Incandescent Up to 100W Retrofit

Version No. 3.4

Measure Overview

Description: This measure replaces Incandescent fixtures up to 100 watts with various technologies including ceramic metal halides, LED lamps, LED luminaire, pin-based CFL, pulse start metal halides, and T8 fixtures. The replacement fixture technology will depend on the specific application and environment.

Actions: Replace working, Retrofit
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting
Applicable to: Commercial, Industrial, and Public Buildings

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x (kW_Base - kW_EE) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = Measure life varies on technology shown in Table 3

Unit Participant Incremental Cost: See Appendix B

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = High Efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = Deemed annual operating hours from Table 2 based on building type

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: Existing fixtures and quantities (retrofits only), installed fixtures and quantities, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned space)

Example:

Replace (1)100W Incandescent fixture with (1) Ceramic Metal halide PAR 39 in an office space

*kWh Savings = (0.100-0.045)*4,439*1.095 = 267.34 kWh*

kW Savings = 0.7(0.100-0.045)*1.254 = 0.048 kW*

*Heating Penalty = (0.100-0.045)*4,439*-0.0023 = -0.562 Dth/year*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System (Ref. 2)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Lighting Measures	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only or Heating & Cooling**
All Except Exterior/Uncond.	1.00	1.254	1.00	1.095	-0.0023
Exterior/Uncond. Space	1.00	1.00	1.00	1.00	0

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 3) and Annual Operating Hours by Building Type (Ref. 4)

Building Type	CF	Hrs
Office	70%	4,439
Restaurant	80%	3,673
Retail	83%	4,719
Grocery/Supermarket	90%	5,802
Warehouse	70%	4,746
Elementary School	71%	2,422
Secondary School	58%	4,311
College	81%	3,540
Health	75%	5,095
Hospital	75%	6,038
Hotel/Motel	21%	3,044
Manufacturing	92%	5,200
Other/Misc.	66%	4,576
24-Hour Facility	100%	8,766
Safety or Code Required	100%	8,766
Exterior lighting	0%	4,903

Table 3: Measure Life

Technology	Measure Life	Reference
Ceramic Metal Halide	13	7
LED Lamps	7.9	8
LED Luminaire	7.9	9
Pin-Based CFL	2.3	10
Pulse Start Metal Halide	15	1
T8 fixtures	15	6

Methodology and Assumptions:

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

For 2012: 100W Incandescent lamps were changed to 72W halogen EISA compliant lamps.

For 2013: in additional to 100W Incandescent lamps already being changed, 75W lamps will be changed to 53W halogen EISA compliant lamps.

For 2014: in addition to 100W and 75W Incandescent lamps already being changed, 60W and 40W lamps will be changed to 43W and 29W halogen EISA compliant lamps.

References:

1. Residential and Commercial/Industrial Lighting and HVAC Measures for use as Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM) June 2007 GDS Associates, Inc.

2. Calculated through energy modeling be FES 2012

3. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version

4. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010

5. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

6. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08 (range from 13-16 years, 15 years was selected)

7. State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report: August 25, 2009

8. LED lamp rated hours of 35,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 7.9 years for measure life

9. LED luminaire rated hours of 35,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 7.9 years for measure life

10. Pin-based CFL lamps rated hours of 10,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 2.3 years for measure life.

11. Survey of manufacturer data and midwest program data. Manufacuter data accessed 8/28/2012

Document Revision History:

Version / Description	Author	Date
1) Lighting calculator from Xcel Energy with rebate calculation deleted and extraneous tabs hidden	Xcel Energy	
2) Incorporated most recent product pairings from Xcel; eliminated calculator; split controls off into a separate spreadsheet, general clean-up to remove Xcel-specific items. Changed 24-hr facility hours to 8700.	JP	
2.1) Corrected some nomenclature issues and eliminated superfluous pairings from the New Construction table. Revised measure lifetimes to equal rated lifetime in hours of new lighting product (supplied by vendor) divided by deemed annual operating hours	JP	
2.2) Corrected some nomenclature issues that were missed.	JP	
2.3) Updated lifetime to use 20 years for fixtures and rated lifetime/annual operating hours for lamps	JP	
2.4) Updated lifetime to clarify to use 20 years for new construction	JP	
2.5) Updated Table 1 (HVAC interactive factors) to account for exterior lighting and fridge/freezer lighting	JP	
2.6) Added provision for Hrs such that Exit Signs always uses 8,760 hours regardless of building type	JP	
3) New format, updated measure life, updated hours, updated CFs, updated resources, updated measure name, reviewed incremental costs and all appear in line with online surveys, manufacturer data, and cost studies	FES	8/31/2012
3.1) Edited existing fixtures to make formatting consistent	JP	2/6/13
3.2) Changed Table 4 references to Appendix B	JP	11/24/13
3.3) Removed rated product lifetime from list of required inputs, changed "exterior" to "exterior/unconditioned space" in HVAC table	JP	3/4/14
3.4) Changed grocery store CF from 69% to 90% to reflect 2011 DEER update (see *DEER Database: 2011 Update Documentation,* Itron, Inc., November 8, 2011)	JP	7/9/14

C/I Lighting - Mercury Vapor Retrofit

Version No. 3.3

Measure Overview

Description:

This measure evaluates mercury vapor fixtures replaced by pulse start metal halides, high bay fluorescent fixtures, high pressure sodium fixtures, parking garage fluorescent fixtures, and ceramic metal halides.

Pulse start metal halide systems typically consume 20 percent less energy than mercury vapor systems, produce the same light at lower wattages, and can often use more efficient ballasts depending on the application.

High bay fluorescent systems are often utilized in high bay ceiling applications over 15 feet. High bay fluorescent and parking garage fluorescent systems offer lower depreciation rates, better dimming options, virtually instant start-up and re-strike, better color rendition, and reduced glare.

Ceramic metal halides can be utilized to replace mercury vapor systems in lower wattage applications and result in better color rendition, lower wattage consumption, and improved color temperature.

Actions: Replace on fail, replace working

Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x (kW_Base - kW_EE) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = Ceramic Metal Halide 13 years (Ref. 1), High Bay Fluorescent 15 years (Ref. 2), Parking Garage Fluorescent 15 years (Ref. 2), Pulse Start Metal Halide 15 years (Ref. 3)

Unit Participant Incremental Cost: See Appendix B

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = High Efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = Deemed annual operating hours from Table 2 based on building type.

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: Existing fixtures and quantities (retrofits only), installed fixtures and quantities, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned space)

Example:

Replace a 175W mercury vapor fixture with a 4 Lamp F32T8 high bay fixture in a warehouse.

*kWh Savings = (0.205-0.117)*4,746*1.095 = 457.33kWh*

kW Savings = 0.70(0.205-.117)*1.254 = 0.077 kW*

*Heating Penalty = (0.205-0.117)*4,746*-0.0023 = -0.961 Dth/year*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System (Ref. 4)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Lighting Measures	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only or Heating & Cooling**
All except exterior/uncond.	1.00	1.254	1.00	1.095	-0.0023
Exterior/uncond.	1.00	1.00	1.00	1.00	0

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 5) and Annual Operating Hours by Building Type (Ref. 6)

Building Type	CF	Hrs
Office	70%	4,439
Restaurant	80%	3,673
Retail	83%	4,719
Grocery/Supermarket	90%	5,802
Warehouse	70%	4,746
Elementary School	71%	2,422
Secondary School	58%	4,311
College	81%	3,540
Health	75%	5,095
Hospital	75%	6,038
Hotel/Motel	21%	3,044
Manufacturing	92%	5,200
Other/Misc.	66%	4,576
24-Hour Facility	100%	8,766
Safety or Code Required	100%	8,766
Exterior lighting (non-24/7)	0%	4,903

Methodology and Assumptions:

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

References:

1. State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation *Business Programs: Measure Life Study* Final Report: August 25, 2009

2. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08 (range from 13-16 years, 15 years was selected)

3. Residential and Commercial/Industrial Lighting and HVAC Measures for use as Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM) June 2007 GDS Associates, Inc.

4. Calculated through energy modeling be FES 2012

5. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version

6. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and

Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010

7. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

Document Revision History:

Version / Description	Author	Date
1) Lighting calculator from Xcel Energy with rebate calculation deleted and extraneous tabs hidden	Xcel Energy	
2) Incorporated most recent product pairings from Xcel; eliminated calculator; split controls off into a separate spreadsheet, general clean-up to remove Xcel-specific items. Changed 24-hr facility hours to 8700.	JP	
2.1) Corrected some nomenclature issues and eliminated superfluous pairings from the New Construction table. Revised measure lifetimes to equal rated lifetime in hours of new lighting product (supplied by vendor) divided by deemed annual operating hours	JP	
2.2) Corrected some nomenclature issues that were missed.	JP	
2.3) Updated lifetime to use 20 years for fixtures and rated lifetime/annual operating hours for lamps	JP	
2.4) Updated lifetime to clarify to use 20 years for new construction	JP	
2.5) Updated Table 1 (HVAC interactive factors) to account for exterior lighting and fridge/freezer lighting	JP	
2.6) Added provision for Hrs such that Exit Signs always uses 8,760 hours regardless of building type	JP	
3) New format, updated measure life, updated hours, updated CFs, updated resources, updated measure name, reviewed incremental costs and all appear in line with online surveys, manufacturer data, and cost studies	FES	8/17/2012
3.1) Made labeling format consistent in table 3 (fixture wattages and incremental costs), removed "magnetic ballast" from existing fixture names, specified non-integrated electronic ballast for CMHs	JP	2/7/2013
3.2) Changed Table 3 references to Appendix B	JP	11/24/13
3.3) Changed grocery store CF from 69% to 90% to reflect 2011 DEER update (see *DEER Database: 2011 Update Documentation,* Itron, Inc., November 8, 2011)	JP	7/9/14

C/I Lighting - Metal Halide Retrofit

Version No. 3.4

Measure Overview

Description:

This measure evaluates probe start metal halides replaced by pulse start metal halides, high bay fluorescent fixtures, parking garage fluorescent fixtures, and ceramic metal halides. Pulse start metal halide systems typically consume 20 percent less energy than standard metal halide systems, produces the same light at lower wattages, and can often use more efficient ballasts depending on the application.

High bay fluorescent and parking garage fluorescent systems are often utilized in high bay ceiling applications over 15 feet. High bay fluorescent and parking garage fluorescent systems offer lower depreciation rates, better dimming options, virtually instant start-up and re-strike, better color rendition, and reduced glare.

Ceramic metal halides can be utilized to replace probe start metal halides in lower wattage applications and result in better color rendition, lower wattage consumption, and improved color temperature.

Actions: Replace on fail, replace working
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting
Applicable to: Commercial, Industrial, and Public Buildings

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE)xHrsxHVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x (kW_Base - kW_EE) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = Ceramic Metal Halide 13 years (Ref. 1), High Bay Fluorescent 15 years (Ref. 2), Pulse Start Metal Halide 15 years (Ref. 3)

Unit Participant Incremental Cost: See Appendix B

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = High Efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = Deemed annual operating hours from Table 2 based on building type.

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: Existing fixtures and quantities (retrofits only), installed fixtures and quantities, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned space)

Example:

Retrofit 100W metal halide, magnetic ballast installed in a retail space with a PAR 39W ceramic metal halide.

*kWh Savings = (0.13-0.045)*4,719*1.095 = 439.22 kWh*

kW Savings = 0.83(0.13-0.045)*1.254 = 0.0885 kW*

*Heating Penalty = (0.13-0.045)*4,719*-0.0023 = -0.923 Dth/year*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System (Ref. 4)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Lighting Measures	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only or Heating & Cooling
All Except Exterior/Uncond.	1.00	1.254	1.00	1.095	-0.0023
Exterior/Uncond. Space	1.00	1.00	1.00	1.00	0

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 5) and Annual Operating Hours by Building Type (Ref. 6)

Building Type	CF	Hrs
Office	70%	4,439
Restaurant	80%	3,673
Retail	83%	4,719
Grocery/Supermarket	90%	5,802
Warehouse	70%	4,746
Elementary School	71%	2,422
Secondary School	58%	4,311
College	81%	3,540
Health	75%	5,095
Hospital	75%	6,038
Hotel/Motel	21%	3,044
Manufacturing	92%	5,200
Other/Misc.	66%	4,576
24-Hour Facility	100%	8,766
Safety or Code Required	100%	8,766
Exterior lighting (non-24/7)	0%	4,903

Methodology and Assumptions:

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Notes:

New construction wattage tables are available in the CI Lighting New Construction file.
The Energy Independence and Security Act of 2007 legislation sets standards for ballasts used in new metal halide luminaires that operate lamps from 150 to 500 watts. New metal halide luminaires must contain ballasts that meet new efficiency standards. Pulse-start metal halide ballasts must have a minimum ballast efficiency of 88%, magnetic probe-start ballast a minimum efficiency of 94%. New metal halides operating lamps of 150-500 watts manufactured on or after January 1, 2009 contain pulse-start, magnetic or electronic, metal halide ballasts with a minimum efficiency of 88%.

References:

1. State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation *Business Programs: Measure Life Study* Final Report: August 25, 2009

2. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08 (range from 13-16 years, 15 years was selected)

3. Residential and Commercial/Industrial Lighting and HVAC Measures for use as Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM) June 2007 GDS Associates, Inc.

4. Calculated through energy modeling be FES 2012

5. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version

6. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 pg 139. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010

7. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

Document Revision History:

Version / Description	Author	Date
1) Lighting calculator from Xcel Energy with rebate calculation deleted and extraneous tabs hidden	Xcel Energy	
2) Incorporated most recent product pairings from Xcel; eliminated calculator; split controls off into a separate spreadsheet, general clean-up to remove Xcel-specific items. Changed 24-hr facility hours to 8700.	JP	
2.1) Corrected some nomenclature issues and eliminated superfluous pairings from the New Construction table. Revised measure lifetimes to equal rated lifetime in hours of new lighting product (supplied by vendor) divided by deemed annual operating hours	JP	
2.2) Corrected some nomenclature issues that were missed.	JP	
2.3) Updated lifetime to use 20 years for fixtures and rated lifetime/annual operating hours for lamps	JP	
2.4) Updated lifetime to clarify to use 20 years for new construction	JP	
2.5) Updated Table 1 (HVAC interactive factors) to account for exterior lighting and fridge/freezer lighting	JP	

2.6) Added provision for Hrs such that Exit Signs always uses 8,760 hours regardless of building type	JP	
3) New format, updated measure life, updated hours, updated resources, updated measure name, reviewed incremental costs and all appear in line with online surveys, manufacturer data, and cost studies	FES	7/27/2012
3.1) Made label formatting consistent in Table 1 (fixture wattages/costs), eliminated some duplicate combinations, added "non-integrated" to CMH electronic ballasts, labeled all existing devices as probe start metal halides, renamed measure "Probe Start Metal Halide"	JP	2/7/2012
3.2) Changed Table 3 references to Appendix B	JP	11/24/13
3.3) Changed “exterior” to “exterior/unconditioned space” in HVAC table	JP	5/8/14
3.4) Changed grocery store CF from 69% to 90% to reflect 2011 DEER update (see *DEER Database: 2011 Update Documentation,* Itron, Inc., November 8, 2011)	JP	7/9/14

C/I Lighting - New Construction

Version No. 3.4

Measure Overview

Description: The following measures are used in new construction in place of the less efficient standard practice. New construction technologies include ceramic metal halide, integral ballast ceramic metal halide, high bay fluorescent, LED exterior canopy, LED exterior wallpacks, LED exterior area/pole, LED lamps, LED luminaires, low wattage plug in CFLs, low wattage T8, Pin based CFLs, and pulse start metal halides.

Actions: New Construction
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x (kW_Base - kW_EE) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years): See Table 3

Unit Participant Incremental Cost: See Appendix B

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = High Efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = Deemed annual operating hours from Table 2 based on building type

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: Installed fixtures and quantities, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned space)

Example:

Install a 10 lamp F54T5HO high bay fixture instead of a 1000W metal halide fixture in a warehouse space.

*kWh Savings = (1.080-0.585)*4,746*1.095 = 2572.45 kWh*

kW Savings = 0.7(1.080-0.585)*1.254 = 0.435 kW*

*Heating Penalty = (1.080-0.585)*4,746*-0.0023 = -5.40 Dth/year*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System (Ref. 2)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Lighting Measures	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only or Heating & Cooling
All Except Exterior/Uncond.	1.00	1.254	1.00	1.095	-0.0023
Exterior/Uncond. Space	1.00	1.00	1.00	1.00	0

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 3) and Annual Operating Hours by Building Type (Ref. 4)

Building Type	CF	Hrs
Office	70%	4,439
Restaurant	80%	3,673
Retail	83%	4,719
Grocery/Supermarket	90%	5,802
Warehouse	70%	4,746
Elementary School	71%	2,422
Secondary School	58%	4,311
College	81%	3,540
Health	75%	5,095
Hospital	75%	6,038
Hotel/Motel	21%	3,044
Manufacturing	92%	5,200
Other/Misc.	66%	4,576
24-Hour Facility	100%	8,766
Safety or Code Required	100%	8,766
Exterior lighting	0%	4,903

Table 3: Measure Life

Technology	Measure Life	Reference
Ceramic Metal Halide	13	6
Ceramic Metal Halide - Integrated Ballast	13	6
High Bay Fluorescent	15	7
LED Exterior Canopy	10.2	8
LED Exterior (Wall & Area)	10.2	8
LED lamp	2.3	9
LED luminaire	3.4	10
Low wattage plug in CFL	1.8	11
Low wattage T8	15	7
Pin based CFL	2.3	12
Pulse Start Metal Halide	15	13

Methodology and Assumptions:

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Notes:

EPAct 2005 and 2000 DOE Ballast Rule. 2000 DOE Ballast Rule no longer allows ballasts that do not pass the new requirements to be manufactured after July 1, 2010 and EPAct 2005 no longer allows ballasts that do not pass the new requirements to be sold after October 1, 2010.
Ballasts affected by the rulemaking are those that operate:
• T12 4-foot linear and 2-foot U-shaped Rapid Start lamps with medium bi-pin bases
• T12 8-foot Instant Start lamps with single pin bases
• T12 8-foot Rapid Start HO lamps with recessed double contact (RDC) bases
Exceptions to the ballast standards:
• Dimming ballasts that dim to 50% or less of maximum output
• T12 HO ballasts capable of starting at ambient temperatures as low as -20° F or less and for use in outdoor illuminated signs
• Ballasts having a power factor of less than 0.90 and designed and labeled for use only in residential applications.
• 2 foot and 3 foot lamp and ballast systems
2009 DOE Lamp Rulemaking for GSFL and IRL Lamps. New efficiency standards for General Service Fluorescent lamps (GSFLs), linear and U-shaped require these covered lamp types to meet minimum lumen per watt (LPW) requirements; products that do not meet the minimum LPW requirements as of July 14, 2012 can no longer be produced.
The following lamp types are affected by these standards:
Lamp Type| Energy Conservation Standard (lm/W)
4-foot (T8-T12) Medium Bi-pin ≥25W 89/88
2-foot (T8-T12) U-Shaped ≥25W 84/81
8-foot (T8-T12) Single Pin Slimline ≥52W 97/93
8-foot (T8-T12) High Output 92/88
4-foot (T5) Miniature Bi-pin Standard Output ≥26W 86/81
4-foot (T5) Miniature Bi-pin high Output ≥49W 76/72
• New T12 lamps that meet the new standards are now available in the market allowing T12s to still be installed.

References:

1. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08 (range from 13-16 years, 15 years was selected)

2. Calculated through energy modeling be FES 2012

3. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version

4. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy

Evaluation, ACES Deemed Savings Desk Review, November 2010

5. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

6. State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report: August 25, 2009

7. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08 (range from 13-16 years, 15 years was selected)

8. LED exterior canopy, area, and wall pack fixture rated hours of 50,000 is divided by the exterior operating hours of 4,903 to arrive at 10.2 years for measure life.

9. LED lamp rated hours of 10,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 2.3 years for measure life

10. LED luminaire rated hours of 15,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 3.4 years for measure life

11. Measure life for plug in low wattage CFL lamps is based on 8,000 hours of life divided by the average annual operating hours of 4,431 to arrive at 1.81 years

12. CFL lamps rated hours of 10,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 2.3 years for measure life.

13. Residential and Commercial/Industrial Lighting and HVAC Measures for use as Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM) June 2007 GDS Associates, Inc.

Document Revision History:

Version / Description	Author	Date
1) Lighting calculator from Xcel Energy with rebate calculation deleted and extraneous tabs hidden	Xcel Energy	
2) Incorporated most recent product pairings from Xcel; eliminated calculator; split controls off into a separate spreadsheet, general clean-up to remove Xcel-specific items. Changed 24-hr facility hours to 8700.	JP	
2.1) Corrected some nomenclature issues and eliminated superfluous pairings from the New Construction table. Revised measure lifetimes to equal rated lifetime in hours of new lighting product (supplied by vendor) divided by deemed annual operating hours	JP	

2.2) Corrected some nomenclature issues that were missed.	JP	
2.3) Updated lifetime to use 20 years for fixtures and rated lifetime/annual operating hours for lamps	JP	
2.4) Updated lifetime to clarify to use 20 years for new construction	JP	
2.5) Updated Table 1 (HVAC interactive factors) to account for exterior lighting and fridge/freezer lighting	JP	
2.6) Added provision for Hrs such that Exit Signs always uses 8,760 hours regardless of building type	JP	
3) New format, updated measure life, updated hours, updated CFs, updated resources, updated measure name, reviewed incremental costs and all appear in line with online surveys, manufacturer data, and cost studies	FES	8/17/2012
3.1) Made fixture labeling consistent format	JP	2/7/2013
3.2) Changed Table 3 references to Appendix B	JP	11/24/13
3.3) Removed existing fixtures, ballast type from Required Inputs, changed “exterior” to “exterior/unconditioned space” in HVAC table	JP	2/21/14
3.4) Changed grocery store CF from 69% to 90% to reflect 2011 DEER update (see *DEER Database: 2011 Update Documentation,* Itron, Inc., November 8, 2011)	JP	7/9/14

C/I Lighting - Pulse Start Metal Halide Retrofit

Version No. 3.4

Measure Overview

Description:

This measure evaluates pulse start metal halide fixtures replaced by lower wattage pulse start metal halides, high bay fluorescent fixtures, parking garage fluorescents, and ceramic metal halides.

Pulse start metal halide fixtures can be replaced by lower wattage pulse start metal halides when the space they are in is considered over lit.

High bay fluorescent and fluorescent systems are often utilized in high bay ceiling applications over 15 feet. High bay fluorescent and fluorescent systems offer lower depreciation rates, better dimming options, virtually instant start-up and re-strike, better color rendition, and reduced glare.

Ceramic metal halides can be utilized to replace pulse start metal halides in lower wattage applications and result in better color rendition, lower wattage consumption, and improved color temperature.

Actions: Replace on fail, replace working

Target Market Segments: Commercial, Industrial, Public, Other
Target End Uses: Lighting
Applicable to: Commercial, Industrial, and Public Buildings

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x (kW_Base - kW_EE) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = Ceramic Metal Halide 13 years (Ref. 1), High Bay Fluorescent 15 years (Ref. 2), Parking Garage Fluorescent 15 years (Ref. 2), Pulse Start Metal Halide 15 years (Ref. 3)

Unit Participant Incremental Cost: See Appendix B

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = High Efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = Deemed annual operating hours from Table 2 based on building type.

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: Existing fixtures and quantities (retrofits only), installed fixtures and quantities, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned space)

Example:

Replace a 175W pulse start metal halide with a 2 lamp F54 T5HO fixture in a warehouse.

*kWh Savings = (0.189-0.117)*4,746*1.095 = 374.18 kWh*

kW Savings = 0.70(0.189-.117)*1.254 = 0.063 kW*

*Heating Penalty = (0.189-0.117)*4,746*-0.0023 = -0.786 Dth/year*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System (Ref. 4)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Lighting Measures	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only or Heating & Cooling
All Except Exterior/Uncond.	1.00	1.254	1.00	1.095	-0.0023
Exterior/Uncond. Space	1.00	1.00	1.00	1.00	0

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 5) and Annual Operating Hours by Building Type (Ref. 6)

Building Type	CF	Hrs
Office	70%	4,439
Restaurant	80%	3,673
Retail	83%	4,719
Grocery/Supermarket	90%	5,802
Warehouse	70%	4,746
Elementary School	71%	2,422
Secondary School	58%	4,311
College	81%	3,540
Health	75%	5,095
Hospital	75%	6,038
Hotel/Motel	21%	3,044
Manufacturing	92%	5,200
Other/Misc.	66%	4,576
24-Hour Facility	100%	8,766
Safety or Code Required	100%	8,766
Exterior lighting	0%	4,903

Methodology and Assumptions:

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Notes:

* New construction wattage tables are available in the CI Lighting New Construction file.

* The Energy Independence and Security Act of 2007 legislation sets standards for ballasts used in new metal halide luminaires that operate lamps from 150 to 500 watts. New metal halide luminaires must contain ballasts that meet new efficiency standards. Pulse-start metal halide ballasts must have a minimum ballast efficiency of 88%, magnetic probe-start ballast a minimum efficiency of 94%. New metal halides operating lamps of 150-500 watts manufactured on or after January 1, 2009 contain pulse-start, magnetic or electronic, metal halide ballasts with a minimum efficiency of 88%.

References:

1. State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation *Business Programs: Measure Life Study* Final Report: August 25, 2009

2. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08 (range from 13-16 years, 15 years was selected)

3. Residential and Commercial/Industrial Lighting and HVAC Measures for use as Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM) June 2007 GDS Associates, Inc.

4. Calculated through energy modeling be FES 2012

5. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version

6. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 section 6.5. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010

7. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

Document Revision History:

Version / Description	Author	Date
1) Lighting calculator from Xcel Energy with rebate calculation deleted and extraneous tabs hidden	Xcel Energy	
2) Incorporated most recent product pairings from Xcel; eliminated calculator; split controls off into a separate spreadsheet, general clean-up to remove Xcel-specific items. Changed 24-hr facility hours to 8700.	JP	
2.1) Corrected some nomenclature issues and eliminated superfluous pairings from the New Construction table. Revised measure lifetimes to equal rated lifetime in hours of new lighting product (supplied by vendor) divided by deemed annual operating hours	JP	
2.2) Corrected some nomenclature issues that were missed.	JP	
2.3) Updated lifetime to use 20 years for fixtures and rated lifetime/annual operating hours for lamps	JP	
2.4) Updated lifetime to clarify to use 20 years for new construction	JP	
2.5) Updated Table 1 (HVAC interactive factors) to account for exterior lighting and fridge/freezer lighting	JP	
2.6) Added provision for Hrs such that Exit Signs always uses 8,760 hours regardless of building type	JP	
3) New format, updated measure life, updated hours, updated CFs, updated resources, updated measure name, reviewed incremental costs and all appear in line with online surveys, manufacturer data, and cost studies	FES	8/17/2012

3.1) Made lighting fixture naming consistent, correct some retrofit category names	JP	2/7/2013
3.2) Changed Table 3 references to Appendix B	JP	11/24/13
3.3) Changed “exterior” to “exterior/unconditioned space” in HVAC table	JP	5/8/14
3.4) Changed grocery store CF from 69% to 90% to reflect 2011 DEER update (see *DEER Database: 2011 Update Documentation,* Itron, Inc., November 8, 2011)	JP	7/9/14

C/I Lighting - Refrigerator/Freezer Case LEDs

Version No. 2.2

Measure Overview

Description: This measure involves replacement of existing fluorescent refrigerated case lighting with Design Lights Consortium-qualified (DLC) LED fixtures.

Actions: Replace on Fail, Replace Working
Target Market Segments: Commercial, Industrial
Target End Uses: Lighting

Applicable to: Grocery stores, convenience stores and other refrigerated sales facilities

Algorithms

Unit kWh Savings per Year = (kW_base - kW_eff) x Hrs x (1 + Refr_Factor)

Unit Peak kW Savings = CF x (kW_base - kW_eff) x (1 + Refr_Factor)

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 3)

Unit Participant Incremental Cost = Efficient fixture cost. See Appendix B.

Where:

kW_base = Baseline fixture wattage, see Appendix B

kW_eff = Efficient fixture wattage, see Appendix B

Hrs = 6,205 hours (Ref. 1)

CF = 90%; Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. (Ref. 2)

Refr_Factor = 0.40 (for refrigerator applications) (Ref. 4)
= 0.77 (for freezer applications) (Ref. 4)

Required from Customer/Contractor: Unit type (refrigerator or freezer), existing fixtures, installed fixtures.

Example:

A convenience store retrofits its reach-in cooler with LED lights.

Unit kWh Savings per Year = (0.076 kW - 0.038 kW) x (6,205 hours) x (1 + 0.40) = 330 kWh

Unit Peak kW Savings = 90% x (0.076 kW - 0.038 kW) x (1 + 0.40) = 0.0479 kW

Deemed Input Tables:

Notes:

The Design Lights Consortium is a collaboration of utility companies and regional energy efficiency organizations that provide criteria and guidelines as well as a qualified products list (QPL) for high-efficiency, high-quality LED products. For more information visit: www.designlights.org

References:

1. State of Ohio Energy Efficiency Technical Reference Manual, 2010. Prepared by Vermont Energy Investment Corporation. Pages 180-182.

2. State of Wisconsin Public Service Commission of Wisconsin "Focus on Energy Evaluation Business Programs: Deemed Savings Parameter Development", KEMA, November 13, 2009, Page A-14.

3. Assumes 6,205 hrs per year operation (17 hrs/day) and a lifetime of approximately 62,082 hours (this is the average rated life from DLC qualified product list). Accessed 7/31/12.

4. US DOE Publication #46230-00, "Energy Savings Potential for Commercial Refrigeration Equipment", 1996, Arthur C. Little, Inc

5. Based on a review of TRM incremental cost assumptions from Oregon and Vermont, supplemented with completed project information from New York.

Documentation Revision History:

Version / Description	Author	Date
1. Put together worksheet	Franklin Energy Services	7/24/2012
2. Minor revisions; changed name to clarify measure also applies to new construction	JP	2/7/2013
2.1 Changed Table 1 references to Appendix B	JP	11/24/13
2.2 Changed measure to retrofit only to work with Appendix B lighting table	JP	3/4/13

C/I Lighting - Stairwell Fixtures with Integral Occupancy Sensors

Version No. 1.0

Measure Overview

Description: This measure involves replacement of existing fluorescent stairwell fixtures with fluorescent or LED stairwell fixtures with integral occupancy sensors and step-dimming ballasts, allowing for automatic adjustment of light output based on stairwell occupancy.

Actions: Replace on Fail, Replace Working
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x (kW_Base - kW_EE) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 14.4 (Ref. 3)

Unit Participant Incremental Cost: See Table 3

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = High Efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = 8,766: Average annual operating hours, 24/7 operation required by code

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF = 1.0 for 24/7 operation

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: Existing fixtures and quantities replaced, installed fixtures and quantities, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned space)

Example:

Retrofit T8 32W 2-Lamp high efficiency, high ballast factor electronic ballast stairwell fixture with a 20W LED Fixture with Integral Occupancy Sensor with a 70% dimming capability. Stairwell is both heated and cooled.

From Appendix B: kW_Base = 0.074, kW_EE = 0.006

*kWh Savings = (0.074-0.006)*8,766*1.095 = 653 kWh*
kW Savings = 1.0(0.076-0.006)*1.254 = 0.088 kW*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System (Ref. 2)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (MMBtu/kWh)
Lighting Measures	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only or Heating & Cooling**
All Except Exterior/Uncond.	1.00	1.254	1.00	1.095	-0.0023
Exterior/Uncond. Space	1.00	1.00	1.00	1.00	0

Methodology and Assumptions

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

The efficient wattages in Appendix B include multipliers reflecting the rated level of dimming and an average duty cycle of 3% determined from M&V of a large installation sponsored by Xcel Energy.

Notes

New construction wattage tables are available in the CI Lighting New Construction file.

In 2009 the Department of Energy announced new lamp rulemaking for general service fluorescent lamps. The efficiency standard requires general service fluorescent lamps covered in this rulemaking to meet minimum lumen per watt (LPW) requirements; products that do not meet the minimum LPW requirements as of July 14, 2012 can no longer be produced. 700 series T8 lamps affected by this rulemaking have been postponed for two years until July 2014. T12 lamps remain on the same timeline.

References

1. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 pg 139. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010.

2. Calculated through energy modeling be FES 2012

3. Xcel Energy 2013-2015 Triennial CIP Plan (Docket No. E,G002/CIP-12-447). Average of fixture lifetime (20 years) and control lifetime (~8 years).

4. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version

5. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

Document Revision History:

Version / Description	Author	Date
1) New measure	Joe Plummer, DER	2.21.14

C/I Lighting - T8 Standard to Low Wattage Retrofit

Version No. 3.4

Measure Overview

Description: High performance T8 lighting with low wattage lamps incorporates improvements to lamp and ballast technologies. They deliver light levels comparable with standard 32 watt T8 systems at lower wattages and with improved lamp life. This measure replaces 32W standard T8 systems with low watt T8 systems.

Actions: Replace on fail, replace working, new construction
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x (kW_Base - kW_EE) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Yea r= 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 36,000 / Hrs (Ref. 3)

Unit Participant Incremental Cost: See Table 3

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = High Efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = Deemed annual operating hours from Table 2 based on building type.

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: Existing fixtures and quantities (retrofits only), installed fixtures and quantities, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned)

Example:

Retrofit F32T8 32W Lamp in high ballast factor fixture installed in an office space with a F32T8 25W Lamp High Ballast Factor.

*kWh Savings = (0.0368-0.0288)*4,439*1.095 = 38.89 kWh*

kW Savings = 0.70(0.0368-0.0288)*1.254 = 0.007 kW*

*Heating Penalty = (0.0368-0.0288)*4,439*-0.0023 = -0.0817 MMBtu/year*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System (Ref. 2)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (MMBtu/kWh)
Lighting Measures	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only or Heating & Cooling**
All Except Exterior/Uncond.	1.00	1.254	1.00	1.095	-0.0023
Exterior/Uncond. Space	1.00	1.00	1.00	1.00	0

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 5) and Annual Operating Hours by Building Type (Ref. 1)

Building Type	CF	Hrs
Office	70%	4,439
Restaurant	80%	3,673
Retail	83%	4,719
Grocery/Supermarket	90%	5,802
Warehouse	70%	4,746
Elementary School	71%	2,422
Secondary School	58%	4,311
College	81%	3,540
Health	75%	5,095
Hospital	75%	6,038
Hotel/Motel	21%	3,044
Manufacturing	92%	5,200
Other/Misc.	66%	4,576
24-Hour Facility	100%	8,766
Safety or Code Required	100%	8,766
Exterior lighting (non-24/7)	0%	4,903

Methodology and Assumptions:

All low wattage lamps should be located on the Reduced Wattage Consortium of Energy Efficiency (CEE) qualifying products list.

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Notes:

New construction wattage tables are available in the CI Lighting New Construction file.

In 2009 the Department of Energy announced new lamp rulemaking for general service fluorescent lamps. The efficiency standard requires general service fluorescent lamps covered in this rulemaking to meet minimum lumen per watt (LPW) requirements; products that do not meet the minimum LPW requirements as of July 14, 2012 can no longer be produced. 700 series T8 lamps affected by this rulemaking have been postponed for two years until July 2014. T12 lamps remain on the same timeline.

References:

1. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 pg 139. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final

Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010.

2. Calculated through energy modeling be FES 2012

3. Product life assumption of 36,000 hours determined from survey of on-line retailers, July 2012

4. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version

5. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

Document Revision History:

Version / Description	Author	Date
1) Lighting calculator from Xcel Energy with rebate calculation deleted and extraneous tabs hidden	Xcel Energy	
2) Incorporated most recent product pairings from Xcel; eliminated calculator; split controls off into a separate spreadsheet, general clean-up to remove Xcel-specific items. Changed 24-hr facility hours to 8700.	JP	
2.1) Corrected some nomenclature issues and eliminated superfluous pairings from the New Construction table. Revised measure lifetimes to equal rated lifetime in hours of new lighting product (supplied by vendor) divided by deemed annual operating hours	JP	
2.2) Corrected some nomenclature issues that were missed.	JP	
2.3) Updated lifetime to use 20 years for fixtures and rated lifetime/annual operating hours for lamps	JP	
2.4) Updated lifetime to clarify to use 20 years for new construction	JP	
2.5) Updated Table 1 (HVAC interactive factors) to account for exterior lighting and fridge/freezer lighting	JP	
2.6) Added provision for Hrs such that Exit Signs always uses 8,760 hours regardless of building type	JP	
3) New format, updated measure life, updated hours, updated resources, energy code information added, reviewed incremental cost and it is in line with other studies.	FES	7/27/2012
3.1) Changed measure life from deemed figure to formula based on annual operating hours, minor revisions	JP	2/7/2013
3.2) Changed Table 3 references to Appendix B	JP	11/24/13
3.3) Removed rated product lifetime from required inputs, changed “exterior” to “exterior/unconditioned space” in HVAC table	JP	3/4/14
3.4) Changed grocery store CF from 69% to 90% to reflect 2011 DEER update (see *DEER Database: 2011 Update Documentation,* Itron, Inc., November 8, 2011), added reference for product life assumption	JP	7/9/14

C/I Lighting - T12 8-Foot Retrofit

Version No. 3.5

Measure Overview

Description: This measure evaluates the replacement of 8 foot T12 lamps and magnetic or electronic ballasts with energy efficient T8, T5, and T5HO lamps and ballasts. The replacements can be 8 foot or 4 foot lamps. Changing from T12 lamp and ballast systems to T8, T5, or T5HO systems will reduce the energy consumption of the system while maintaining similar light outputs.

Actions: Replace Working, Replace on Fail
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x (kW_Base - kW_EE) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = Energy Standard exempt T12 HO ballasts for outdoor signs and electronic ballast T12s - 15 years (Ref. 1), Nonexempt 8 foot magnetic ballast T12s are 4 years in 2013, 3 years in 2014, 2 years in 2015, and 1 year in 2016 (Ref. 6)

Unit Participant Incremental Cost : See Appendix B

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = High Efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = Deemed annual operating hours from Table 2 based on building type - All exit signs operate 24 hours/day

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: Existing fixtures and quantities, installed fixtures and quantities, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned)

Example:

Replace 2 T12 96-inch 110W lamps and one magnetic ballast with 2 T8 48-inch 32W lamps and one electronic/ high efficiency/ high ballast factor ballast in an office space that is heated and cooled.

*kWh Savings = (0.205-0.074)*4,439*1.095 = 636.8 kWh*

kW Savings = 0.7(0.205-0.074)*1.254 = 0.115 kW*

*Heating Penalty = (0.205-0.074)*4,439*-0.0023 = -1.34 Dth/year*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System (Ref. 2)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Lighting Measures	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only or Heating & Cooling
All Except Exterior/Uncond.	1.00	1.254	1.00	1.095	-0.0023
Exterior/Uncond. Space	1.00	1.00	1.00	1.00	0

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 3) and Annual Operating Hours by Building Type (Ref. 4)

Building Type	CF	Hrs
Office	70%	4,439
Restaurant	80%	3,673
Retail	83%	4,719
Grocery/Supermarket	90%	5,802
Warehouse	70%	4,746
Elementary School	71%	2,422
Secondary School	58%	4,311
College	81%	3,540
Health	75%	5,095
Hospital	75%	6,038
Hotel/Motel	21%	3,044
Manufacturing	92%	5,200
Other/Misc.	66%	4,576
24-Hour Facility	100%	8,766
Safety or Code Required	100%	8,766
Exterior lighting	0%	4,903

Methodology and Assumptions:

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Measure Life is reduced based on remaining useful life of magnetic ballasts in the market place. Using the analysis completed in the Texas Docket 39146 Appendix C, a current remaining useful life of T12 magnetic ballasts at the end of 2012 is 4.1 years, or 4 years. The following documents were used in this analysis:
-"Fluorescent Lamp Ballasts Preliminary Analytical Tools: National Impact Analysis" (Ref. 7)
-"Fluorescent Lamp Ballast Technical Support Document for the Final Rule, 2000" (Ref. 8)

The Illinois Statewide Technical Reference Manual goes further to conclude the measure life should decrease from four years in 2012 to three years in 2013, two years in 2014, and one year in 2015. (Ref. 9)

Notes:

EPAct 2005 and 2000 DOE Ballast Rule. 2000 DOE Ballast Rule no longer allows ballasts that do not pass the new requirements to be manufactured after July 1, 2010 and EPAct 2005 no longer allows ballasts that do not pass the new requirements to be sold after October 1,

2010.
Ballasts affected by the rulemaking are those that operate:
• T12 4-foot linear and 2-foot U-shaped Rapid Start lamps with medium bi-pin bases
• T12 8-foot Instant Start lamps with single pin bases
• T12 8-foot Rapid Start HO lamps with recessed double contact (RDC) bases
Exceptions to the ballast standards:
• Dimming ballasts that dim to 50% or less of maximum output
• T12 HO ballasts capable of starting at ambient temperatures as low as -20° F or less and for use in outdoor illuminated signs
• Ballasts having a power factor of less than 0.90 and designed and labeled for use only in residential applications.
• 2 foot and 3 foot lamp and ballast systems
2009 DOE Lamp Rulemaking for GSFL and IRL Lamps. New efficiency standards for General Service Fluorescent lamps (GSFLs), linear and U-shaped require these covered lamp types to meet minimum lumen per watt (LPW) requirements; products that do not meet the minimum LPW requirements as of July 14, 2012 can no longer be produced.
The following lamp types are affected by these standards:
Lamp Type| Energy Conservation Standard (lm/W)
4-foot (T8-T12) Medium Bi-pin ≥25W 89/88
2-foot (T8-T12) U-Shaped ≥25W 84/81
8-foot (T8-T12) Single Pin Slimline ≥52W 97/93
8-foot (T8-T12) High Output 92/88
4-foot (T5) Miniature Bi-pin Standard Output ≥26W 86/81
4-foot (T5) Miniature Bi-pin high Output ≥49W 76/72
• New T12 lamps that meet the new standards are now available in the market allowing T12s to still be installed.

References:

1. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08 (range from 13-16 years, 15 years was selected)

2. Calculated through energy modeling be FES 2012

3. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version

4. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010

5. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

6. Measure life phase out is based on a combination of Texas Docket 39146 and the Illinois Statewide Technical Reference Manual. See methodology and assumptions for more details.

7. DOE 2010b "Fluorescent Lamp Ballasts Preliminary Analytical Tools: National Impact Analysis" U.S. Department of Energy: 2010.

8. DOE 2000b. "Fluorescent Lamp Ballast Technical Support Document for the Final Rule, 2000." September 2000.

9. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5.

Document Revision History:

Version / Description	Author	Date
1) Lighting calculator from Xcel Energy with rebate calculation deleted and extraneous tabs hidden	Xcel Energy	
2) Incorporated most recent product pairings from Xcel; eliminated calculator; split controls off into a separate spreadsheet, general clean-up to remove Xcel-specific items. Changed 24-hr facility hours to 8700.	JP	
2.1) Corrected some nomenclature issues and eliminated superfluous pairings from the New Construction table. Revised measure lifetimes to equal rated lifetime in hours of new lighting product (supplied by vendor) divided by deemed annual operating hours	JP	
2.2) Corrected some nomenclature issues that were missed.	JP	
2.3) Updated lifetime to use 20 years for fixtures and rated lifetime/annual operating hours for lamps	JP	
2.4) Updated lifetime to clarify to use 20 years for new construction	JP	
2.5) Updated Table 1 (HVAC interactive factors) to account for exterior lighting and fridge/freezer lighting	JP	
2.6) Added provision for Hrs such that Exit Signs always uses 8,760 hours regardless of building type	JP	
3) New format, updated measure life, updated hours, updated CFs, updated resources, updated measure name, reviewed incremental costs and all appear in line with online surveys, manufacturer data, and cost studies	FES	8/17/2012
3.1) Updated T12 magnetic ballast measure life	FES	8/31/2012

3.2) Updated fixture labeling to make format consistent, minor revisions, changed measure name	JP	2/8/2013
3.3) Changed Table 3 references to Appendix B	JP	11/24/13
3.4) Changed “exterior” to “exterior/unconditioned space” in HVAC table	JP	5/8/14
3.5) Changed grocery store CF from 69% to 90% to reflect 2011 DEER update (see *DEER Database: 2011 Update Documentation,* Itron, Inc., November 8, 2011)	JP	7/9/14

C/I Lighting - T12 Up to 4-Foot Retrofit

Version No. 3.5

Measure Overview

Description: This measure evaluates the replacement of T12 lamps and magnetic or electronic ballasts up to 4 feet in length with energy efficient T8, T5, and T5HO lamps and ballasts. The replacement of T12 lamps and ballasts with T8, T5, and T5HO lamp and ballast systems results in a lower wattage system with similar light output.

Actions: Replace working, Retrofit
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x (kW_Base - kW_EE) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = Energy Standard exempts 2 foot, 3 foot, and electronic ballast T12s - 15 years (Ref. 1), Nonexempt 4 foot magnetic ballast T12s are 4 years in 2013, 3 years in 2014, 2 years in 2015, and 1 year in 2016 (Ref. 6)

Unit Participant Incremental Cost: See Appendix B

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = High Efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = Deemed annual operating hours from Table 2 based on building type - All exit signs operate 24 hours/day

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: Existing fixtures and quantities, installed fixtures and quantities, building type, HVAC system (heating only, heating & cooling, or exterior/unconditioned)

Example:

Replace (1) T12 48" 40W two-lamp fixture with magnetic ballast with (1) T8 24" 17W two-lamp fixture with a high efficiency, low ballast factor electronic ballast in an office space that is heated and cooled.

From Appendix B:

Fixture codes are FT12-48-GEN-40-2-Fixt-MB-STD and FT8-24-17-2-Fixt-EB-HE-LBF.

*kWh Savings = (0.097-0.027)*4,439*1.095 = 340.2 kWh*

kW Savings = 0.7(0.097-0.027)*1.254 = 0.061 kW*

Measure lifetime = 15 years

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System (Ref. 2)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Lighting Measures	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only or Heating & Cooling**
All except Exterior/Uncond.	1.00	1.254	1.00	1.095	-0.0023
Exterior/Uncond.	1.00	1.00	1.00	1.00	0

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 3) and Annual Operating Hours by Building Type (Ref. 4)

Building Type	CF	Hrs
Office	70%	4,439
Restaurant	80%	3,673
Retail	83%	4,719
Grocery/Supermarket	90%	5,802
Warehouse	70%	4,746
Elementary School	71%	2,422
Secondary School	58%	4,311
College	81%	3,540
Health	75%	5,095
Hospital	75%	6,038
Hotel/Motel	21%	3,044
Manufacturing	92%	5,200
Other/Misc.	66%	4,576
24-Hour Facility	100%	8,766
Safety or Code Required	100%	8,766
Exterior lighting	0%	4,903

Methodology and Assumptions:

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Measure Life is reduced based on remaining useful life of magnetic ballasts in the market place. Using the analysis completed in the Texas Docket 39146 Appendix C, a current remaining useful life of T12 magnetic ballasts at the end of 2012 is 4.1 years, or 4 years. The following documents were used in this analysis:
-"Fluorescent Lamp Ballasts Preliminary Analytical Tools: National Impact Analysis" (Ref. 7)
-"Fluorescent Lamp Ballast Technical Support Document for the Final Rule, 2000" (Ref. 8)

The Illinois Statewide Technical Reference Manual goes further to conclude the measure life should decrease from four years in 2012 to three years in 2013, two years in 2014, and one year in 2015. (Ref. 9)

Notes:

EPAct 2005 and 2000 DOE Ballast Rule. 2000 DOE Ballast Rule no longer allows ballasts that do not pass the new requirements to be manufactured after July 1, 2010 and EPAct 2005 no longer allows ballasts that do not pass the new requirements to be sold after October 1, 2010.
Ballasts affected by the rulemaking are those that operate:
• T12 4-foot linear and 2-foot U-shaped Rapid Start lamps with medium bi-pin bases
• T12 8-foot Instant Start lamps with single pin bases
• T12 8-foot Rapid Start HO lamps with recessed double contact (RDC) bases
eptions to the ballast standards:
• Dimming ballasts that dim to 50% or less of maximum output
• T12 HO ballasts capable of starting at ambient temperatures as low as -20° F or less and for use in outdoor illuminated signs
• Ballasts having a power factor of less than 0.90 and designed and labeled for use only in residential applications.
• 2 foot and 3 foot lamp and ballast systems
2009 DOE Lamp Rulemaking for GSFL and IRL Lamps. New efficiency standards for General Service Fluorescent lamps (GSFLs), linear and U-shaped require these covered lamp types to meet minimum lumen per watt (LPW) requirements; products that do not meet the minimum LPW requirements as of July 14, 2012 can no longer be produced.
The following lamp types are affected by these standards:
Lamp Type| Energy Conservation Standard (lm/W)
4-foot (T8-T12) Medium Bi-pin ≥25W 89/88
2-foot (T8-T12) U-Shaped ≥25W 84/81
8-foot (T8-T12) Single Pin Slimline ≥52W 97/93
8-foot (T8-T12) High Output 92/88
4-foot (T5) Miniature Bi-pin Standard Output ≥26W 86/81
4-foot (T5) Miniature Bi-pin high Output ≥49W 76/72
• New T12 lamps that meet the new standards are now available in the market allowing T12s to still be installed.

References:

1. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08 (range from 13-16 years, 15 years was selected)

2. Calculated through energy modeling be FES 2012

3. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version

4. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010

5. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

6. Measure life phase out is based on a combination of Texas Docket 39146 and the Illinois Statewide Technical Reference Manual. See methodology and assumptions for more details.

7. DOE 2010b "Fluorescent Lamp Ballasts Preliminary Analytical Tools: National Impact Analysis" U.S. Department of Energy: 2010.

8. DOE 2000b. "Fluorescent Lamp Ballast Technical Support Document for the Final Rule, 2000." September 2000.

9. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5.

Document Revision History:

Version / Description	Author	Date
1) Lighting calculator from Xcel Energy with rebate calculation deleted and extraneous tabs hidden	Xcel Energy	
2) Incorporated most recent product pairings from Xcel; eliminated calculator; split controls off into a separate spreadsheet, general clean-up to remove Xcel-specific items. Changed 24-hr facility hours to 8700.	JP	
2.1) Corrected some nomenclature issues and eliminated superfluous pairings from the New Construction table. Revised measure lifetimes to equal rated lifetime in hours of new lighting product (supplied by vendor) divided by deemed annual operating hours	JP	
2.2) Corrected some nomenclature issues that were missed.	JP	
2.3) Updated lifetime to use 20 years for fixtures and rated lifetime/annual operating hours for lamps	JP	
2.4) Updated lifetime to clarify to use 20 years for new construction	JP	
2.5) Updated Table 1 (HVAC interactive factors) to account for exterior lighting and fridge/freezer lighting	JP	
2.6) Added provision for Hrs such that Exit Signs always uses 8,760 hours regardless of building type	JP	
3) New format, updated measure life, updated hours, updated CFs, updated resources, updated measure name, reviewed incremental costs and all appear in line with online surveys, manufacturer data, and cost studies	FES	8/17/2012
3.1) Updated T12 magnetic ballast measure life	FES	8/31/2012
3.2) Updated fixture labeling to make format consistent, minor revisions	JP	2/8/2013
3.3) Changed Table 3 references to Appendix B	JP	11/24/13
3.4) Changed “exterior” to “exterior/unconditioned space” in HVAC table	JP	5/8/14
3.5) Changed grocery store CF from 69% to 90% to reflect 2011 DEER update (see *DEER Database: 2011 Update Documentation,* Itron, Inc., November 8, 2011)	JP	7/9/14

C/I Lighting - T8 Optimization

Version No. 3.5

Measure Overview

Description: Optimization means reducing the light output of a fluorescent fixture in an overlit space through permanently reducing the quantity of linear fluorescent lamps used in a fixture, or switching to a shorter length fixture with the same quantity of lamps. Optimization must be done properly so as to maintain the minimum light level required by code. This measure includes both lamp and ballast changes and not lamp changes only.

Actions: Replace working
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x (kW_Base - kW_EE) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years (Ref. 1)

Unit Participant Incremental Cost: See Appendix B

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = High Efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = Deemed annual operating hours from Table 2 based on building type.

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: Existing fixtures and quantities (retrofits only), installed fixtures and quantities, building type, HVAC system (heating only, heating & cooling, exterior/uncondioned)

Example:

Delamp (2) F32T8 48" 32W Lamp with a high efficiency, high ballast factor electronic ballast installed in an office space to (1) F32T8 48" 32W Lamp with a high efficiency, high ballast factor electronic ballast.

*kWh Savings = (0.0736-0.0368)*4,439*1.095 = 178.87 kWh*

kW Savings = 0.70(0.0736-0.0368)*1.254 = 0.0323kW*

*Heating Penalty = (0.0736-0.0368)*4,439*-0.0023 = -0.3757Dth/year*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System (Ref. 2)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Lighting Measures	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only or Heating & Cooling**
All Except Exterior/Uncond.	1.00	1.254	1.00	1.095	-0.0023
Exterior/Uncond.	1.00	1.00	1.00	1.00	0

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 3) and Annual Operating Hours by Building Type (Ref. 4)

Building Type	CF	Hrs
Office	70%	4,439
Restaurant	80%	3,673
Retail	83%	4,719
Grocery/Supermarket	90%	5,802
Warehouse	70%	4,746
Elementary School	71%	2,422
Secondary School	58%	4,311
College	81%	3,540
Health	75%	5,095
Hospital	75%	6,038
Hotel/Motel	21%	3,044
Manufacturing	92%	5,200
Other/Misc.	66%	4,576
24-Hour Facility	100%	8,766
Safety or Code Required	100%	8,766
Exterior lighting	0%	4,903

Methodology and Assumptions:

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Notes:

New construction wattage tables are available in the CI Lighting New Construction file.
In 2009 the Department of Energy announced new lamp rulemaking for general service fluorescent lamps. The efficiency standard requires general service fluorescent lamps covered in this rulemaking to meet minimum lumen per watt (LPW) requirements; products that do not meet the minimum LPW requirements as of July 14, 2012 can no longer be produced. 700 series T8 lamps affected by this rulemaking have been postponed for two years until July 2014. T12 lamps remain on the same timeline.

References:

1. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08 (range from 13 - 16 years, 15 was selected)

2. Calculated through energy modeling be FES 2012

3. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version

4. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 pg 139. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010

5. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

Document Revision History:

Version / Description	Author	Date
1) Lighting calculator from Xcel Energy with rebate calculation deleted and extraneous tabs hidden	Xcel Energy	
2) Incorporated most recent product pairings from Xcel; eliminated calculator; split controls off into a separate spreadsheet, general clean-up to remove Xcel-specific items. Changed 24-hr facility hours to 8700.	JP	
2.1) Corrected some nomenclature issues and eliminated superfluous pairings from the New Construction table. Revised measure lifetimes to equal rated lifetime in hours of new lighting product (supplied by vendor) divided by deemed annual operating hours	JP	
2.2) Corrected some nomenclature issues that were missed.	JP	
2.3) Updated lifetime to use 20 years for fixtures and rated lifetime/annual operating hours for lamps	JP	
2.4) Updated lifetime to clarify to use 20 years for new construction	JP	
2.5) Updated Table 1 (HVAC interactive factors) to account for exterior lighting and fridge/freezer lighting	JP	
2.6) Added provision for Hrs such that Exit Signs always uses 8,760 hours regardless of building type	JP	

3) New format, updated measure life, updated hours, updated references, added description	FES	7/27/2012
3.1) Made fixture labeling consistent, changed description to specify that measure is for both lamp & ballast replacement only (not lamp only.)	JP	2/7/2013
3.2) Changed Table 3 references to Appendix B	JP	11/24/13
3.3) Changed name to “T8 optimization” since the measure includes more than delamping and changed description accordingly.	JP	2/21/14
3.4) Removed rated product lifetime in hours from required inputs, changed “exterior” to “exterior/unconditioned space” in HVAC table	JP	3/4/14
3.5) Changed grocery store CF from 69% to 90% to reflect 2011 DEER update (see *DEER Database: 2011 Update Documentation,* Itron, Inc., November 8, 2011)	JP	7/9/14

C/I Motors

Version No. 2.0

Measure Overview

Description: This measure includes one-for-one replacement of working or failed/near-failure 1-200 hp motors with motors that meet or exceed NEMA Premium Efficiency levels in industrial and non-industrial applications, as well as installation of motors in new construction.

For replacement of working motors, the new motor efficiency must be at least NEMA Premium Efficiency. For replacement of failed/near-failure motors or new construction, the new motor efficiency must exceed NEMA Premium Efficiency.

Actions: Replace Working, Replace on Fail, New Construction
Target Market Segments: Commercial, Industrial
Target End Uses: Fans, Pumps, Motors, HVAC, Process

Applicable to: Motors in industrial and HVAC applications.

Algorithms

Unit kWh Savings per Year = HP x LF x Conversion x (1/Eff_base – 1/Eff_new) x Hrs

Unit Peak kW Savings = HP x LF x Conversion x (1/Eff_base – 1/Eff_new) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 6 years (Replace Working), 20 years (Replace on Fail, New Construction) (Ref. 1, 2, 4)

Unit Participant Incremental Cost = Incr. Cost for EPACT to NEMA Premium Efficiency or EPACT to Enhanced NEMA Premium (Replacing Working); Incr. Cost for NEMA Premium Efficiency to Enhanced NEMA Premium (Replace on Fail and New Construction). See Appendix C. (Ref. 6)

Where:

Hrs = Deemed annual operating hours by end use (non-industrial applications, see Table 2) or motor HP (industrial applications, see Table 1.)

LF = Motor load factor, deemed at 75% (Ref. 1, 4)

HP = Rated horsepower of new motor

Eff_new = Efficiency of new motor. Eff_new = NEMA Premium Efficiency or NEMA Premium Efficiency + 1%. See Appendix C.

Eff_base = Baseline motor efficiency. Eff_base = EPACT efficency (Replace Working), NEMA Premium Efficiency (Replace on Fail, New Construction). See Appendix C.

Conversion = Standard conversion from hp to kW = 0.746 kW/hp

CF = Coincidence Factor = 0.78 (Ref. 1, 2)

Required from Customer/Contractor: New Motor Enclosure Type (ODP/TEFC), RPM, Horsepower, Efficiency; Action Type (Replace on Fail, Replace Working, or New Construction); Building Type and Application (see Table 2).

Deemed Input Tables

Table 1: Deemed annual operating hours by motor horsepower for industrial applications (Ref. 3)

Motor HP	Hrs
5	2,745
7.5	3,391
10	3,391
15	3,391
20	3,391
25	4,067
30	4,067
40	4,067
50	4,067
60	5,329
75	5,329
100	5,329
125	5,200
150	5,200
200	5,200

Table 2: Deemed annual operating hours by building type and application (Ref. 4)

Building Type and Application	Hrs
Office HVAC Pump	2,000
Retail HVAC Pump	2,000
Hospitals HVAC Pump	2,754
Elem/Sec Schools HVAC Pump	2,190
Restaurant HVAC Pump	2,000
Warehouse HVAC Pump	2,241
Hotels/Motels HVAC Pump	4,231
Grocery HVAC Pump	2,080
Health HVAC Pump	2,559
College/Univ HVAC Pump	3,641
Office Ventilation Fan	6,192
Retail Ventilation Fan	3,261
Hospitals Ventilation Fan	8,374
Elem/Sec Schools Ventilation Fan	3,699
Restaurant Ventilation Fan	4,155

Warehouse Ventilation Fan	6,389
Hotels/Motels Ventilation Fan	3,719
Grocery Ventilation Fan	6,389
Health Ventilation Fan	2,000
College/Univ Ventilation Fan	3,631
Office Other Non-Industrial Application	4,500
Retail Other Non-Industrial Application	4,500
Hospitals Other Non-Industrial Application	4,500
Elem/Sec Schools Other Non-Industrial Application	4,500
Restaurant Other Non-Industrial Application	4,500
Warehouse Other Non-Industrial Application	4,500
Hotels/Motels Other Non-Industrial Application	4,500
Grocery Other Non-Industrial Application	4,500
Health Other Non-Industrial Application	4,500
College/Univ Other Non-Industrial Application	4,500
Industrial/Manufacturing	See Table 1

Methodology and Assumptions

Measure lives for replacement of failed motors or motors in new construction was 15-20 years in most TRMs prior to the EISA standard for motors taking effect in December 2010. No sources were found for lifetime of early replacement motors since most states have disallowed rebates for industrial Premium Efficiency motors. However, a review of several TRMs showed that for other measures, the lifetime of early replacements is typically about one-third of the full measure life. Therefore, the lifetime of this measure was set to 6 years (approximately one-third of 15-20 years.)

Notes

According to the EISA standard, general purpose motors (subtype I) manufactured after December 19, 2010, with a power rating of at least 1 horsepower but not greater than 200 horsepower, shall have a nominal full-load efficiency that is not less than as defined in NEMA MG– 1 (2006) Table 12–12 (aka “NEMA Premium®” efficiency levels).

References

1. NYSERDA (New York State Energy Research and Development Authority); NY Energy $mart Programs Deemed Savings Database - Source for coincidence factor, measure life, and motor load factor

2. Franklin Energy Services review, November 2013

3. United States Industrial Electric Motor Systems Market Opportunities Assessment, EERE, US DOE, Dec 2002 - Source for operating hours for industrial motors and source for motor load factor data (Tables 1-18 and 1-19)

4. Efficiency Vermont's Technical Reference User Manual, 2004 - Source for operating hours for commercial motors (p.15) and source for measure life and source for existing motor efficiencies and source for motor load factor default value

5. CEE (Consortium for Energy Efficiency) Premium Efficiency Motors Initiative – source for premium motor efficiencies

6. Xcel Energy Minnesota Electric and Natural Gas Conservation Improvement Program Plan for 2013-2015 (Docket No. E,G002/CIP-12-447) – source for incremental costs.

Documentation Revision History:

Version / Description	Author	Date
1 New spec	JP	11.13.13
2 Design changes to accommodate Replace on Fail and New Construction in addition to Replace Working, corrected incremental cost information.	JP	5.9.14

C/I Refrigeration - Anti-Sweat Heat Control

Version No. 1.2

Measure Overview

Description: Glass doors on refrigerator and freezer cases can have anti-sweat or anti-condensate heaters in the frames and mullions of the case. These heaters operate continuously in order to prevent condensation/frosting on the glass and frame that occurs when the surface temperature is below the dew point of the surrounding air. Anti-sweat heater controls control the operation of these heaters so that they do not run continuously when not needed (lower dew point in the air as typically occurs in winter). Anti-sweat heaters are only required to operate at full capacity when the space humidity is 55%. This results in energy savings due to reduced operation of the heater elements.

Actions: Modify, New Construction
Target Market Segments: Commercial, Industrial
Target End Uses: Refrigeration

Applicable to: Commercial and Industrial Refrigeration

Algorithms

Unit kWh Savings per Year = kW_base * n_door * ESF * BF * 8766

Unit Peak kW Savings = 0

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $200 (ref. 2)

Where:

kW_base = connected load kW for reach-in cooler or freezer door and frame with a heater. Assumed to be 0.195 kW for freezers and 0.092 kW for coolers (ref. 3)

n_door = number of doors controlled by sensor, actual installed

8766 = operating hours over the course of a year

ESF = Energy Savings Factor; represents the percentage of hours annually that the door heater is powered off due to the controls. Assumed to be 55% for humidity based controls, 70% for conductivity based control (ref. 4)

BF = Bonus Factor; represents the increased savings due to reduction in cooling load inside the cases, and the increase in cooling load in the building space to cool the additional heat generated by the door heaters. Assumed to be 1.36 for low temp, 1.22 for medium temp, and 1.15 for high temp application (ref. 4)

Low Temperature: Freezers, -35F to 0F, Frozen foods, ice cream, etc.
Medium Temperature: Coolers, 0F to 20F, Meat, milk, dairy, etc.
High Temperature: Coolers, 20F to 45F, Floral, Produce, etc.

Required from Customer/Contractor: Equipment type (cooler or freezer), number of doors, temperature (high/medium/low), humidity or conductivity-based control

Example:

Install anti-sweat humidity-based heat control on 2-door low-temperature cooler

Unit kWh Savings per Year = 0.092 * 2 * 0.55 * 1.36 * 8766 = 1206.5

References:

1. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.

2. Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010, Pg. 208-210

3. Based on a range of wattages from two manufacturers and metered data

4. Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010

Documentation Revision History:

Version / Description	Author	Date
1) New measure	Franklin Energy	8/20/2012
1.1) Corrected required inputs, defined temperature ranges, corrected example calculation, changed measure name, removed erroneous 0.9 factor in example calculation, removed Reference 5 referring to 0.9 factor, changed annual hours from 8760 to 8766	JP	11/22/2013
1.2) Eliminated option to provide connected load and removed connected load from required inputs to simply the Smart Measure design, added equipment type to Required Inputs.	JP	3/2/2014

C/I Refrigeration - ENERGY STAR Refrigerator and Freezer

Version No. 2.1

Measure Overview

Description: This measure relates to the installation of a new reach-in commercial refrigerator or freezer meeting ENERGY STAR efficiency standards. In order for this characterization to apply, the efficient equipment is assumed to be a new vertical glass door refrigerator or freezer or vertical chest freezer meeting the minimum ENERGY STAR efficiency level standards.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial, Industrial
Target End Uses: Refrigeration

Applicable to: Commercial and industrial refrigeration

Algorithms

Unit kWh Savings per Year = (kWh_base - kWh_ee) * 365.25

Unit Peak kW Savings = kWh Savings/8766 X CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = See Table 1

Where:

kWh_base = baseline maximum daily energy consumption in kWh, calculated using actual chilled or frozen compartment volume (V) of the efficient unit as shown in Table 2

kWh_ee = efficient maximum daily energy consumption in kWh, calculated using actual chilled or frozen compartment volume (V) of the efficient unit as shown in the Table 3

V = the chilled or frozen compartment volume (ft^3) (as defined in the Association of Home Appliance Manufacturers Standard HRF1–1979), actual installed

8766 = operating hours over the course of a year

365.25 = days per year

CF = Coincidence Factor, assumed to be 0.9 (ref. 2)

Required from Customer/Contractor: Actual installed frozen compartment volume in cubic feet, solid or glass door, refrigerator or freezer

Example:

Install glass door for refrigerator with a volume of 15 ft³

*Unit kWh Savings per Year = ((0.12 * 15 + 3.34) - (0.140 * 15 + 1.050)) * 365.25 = 727 kWh*

*Unit Peak kW Savings = 727/8766 * 0.9 = 0.075 kW*

Deemed Input Tables:

Table 1. The incremental capital cost (ref. 3)

Type	Refrigerator incremental Cost, per unit	Freezer Incremental Cost, per unit
Solid or Glass Door		
0 < V < 15	$143	$142
15 ≤ V < 30	$164	$166
30 ≤ V < 50	$164	$166
V ≥ 50	$249	$407

Table 2. Baseline maximum daily energy consumption in kWh (ref. 4)

Type	kWh_base
Solid Door Refrigerator	0.10 * V + 2.04
Glass Door Refrigerator	0.12 * V + 3.34
Solid Door Freezer	0.40 * V + 1.38
Glass Door Freezer	0.75 * V + 4.10

Table 3. Efficient maximum daily energy consumption in kWh (ref. 5)

Type	Refrigerator	Freezer
	kWhee	kWhee
Solid Door		
0 < V < 15	≤ 0.089V + 1.411	≤ 0.250V + 1.250
15 ≤ V < 30	≤ 0.037V + 2.200	≤ 0.400V – 1.000
30 ≤ V < 50	≤ 0.056V + 1.635	≤ 0.163V + 6.125
V ≥ 50	≤ 0.060V + 1.416	≤ 0.158V + 6.333
Glass Door		
0 < V < 15	≤ 0.118V + 1.382	≤ 0.607V + 0.893
15 ≤ V < 30	≤ 0.140V + 1.050	≤ 0.733V – 1.000
30 ≤ V < 50	≤ 0.088V + 2.625	≤ 0.250V + 13.500
V ≥ 50	≤ 0.110V + 1.500	≤ 0.450V + 3.500

References:

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007

<http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf>

2. TBD

3. Nadel, S., Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, ACEEE, December 2002

4. Energy Policy Act of 2005. Accessed on 7/7/10.

<http://www.epa.gov/oust/fedlaws/publ_109-058.pdf>

5. ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers Partner Commitments Version 2.0, U.S. Environmental Protection Agency, Accessed on 7/7/10.

<http://www.energystar.gov/ia/partners/product_specs/program_reqs/commer_refrig_glass_prog_req.pdf>

Documentation Revision History:

Version / Description	Author	Date
1.) New measure	Franklin Energy	8/20/2012
2.) Corrected example, changed 365 days/yr to 365.25, changed 8760 h/yr to 8766, changed name	JP	2/11/2013
2.1 Corrected example	JP	5/8/2014

C/I Refrigeration - Evaporator Fan Motor Retrofit

Version No. 1.2

Measure Overview

Description: This measure includes replacement of an existing, working standard-efficiency shaded-pole evaporator fan motor in refrigerated/freezer display cases or walk-in coolers with a high efficiency electronically commutated motor (ECM).

Actions: Replace Working
Target Market Segments: Commercial, Industrial
Target End Uses: Refrigeration

Applicable to: Commercial and Industrial Refrigeration

Algorithms

Unit kWh Savings per Year = (W_base - W_ee)/1000 * LF * DC_evap * (1 + 1/(DG * COP)) * 8766

Unit Peak kW Savings = (W_base - W_ee)/1000 * LF * DC_evap * (1 + 1/(DG * COP)) * CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 (Ref. 1)

Unit Participant Incremental Cost = $100 (ref. 1)

Where:

W_base = Input wattage of existing/baseline evaporator fan motor. The value is from nameplate or See Table 1 if unknown.

W_ee = Input wattage of new energy efficient evaporator fan motor. The value is from nameplate or See Table 1 if unknown.

LF = Load Factor of evaporator fan motor. Assumed to be 0.9 (ref. 2)

DC_evap = Duty cycle of evaporator fan motor for refrigerator/freezer. DC_evap = 100% for refrigerator, DC_evap = 94.4% for freezer (ref. 2)

DG = Degradation factor of compressor COP. Assumed to be 0.98 (ref. 2)

COP = Coefficient of performance of compressor in the refrigerator/freezer. COP = 2.5 for refrigerator, COP = 1.3 for freezer (ref. 1, 2)

8766 = Operating hours over the course of a year

CF = Coincidence factor = 0.9 (Ref. 4)

Required from Customer/Contractor: Equipment type (refrig or freezer), Motor category (1-14W, 16-23W, 1/20HP)

Optional inputs from customer/contractor: Input wattages of existing and new evaporator fan motors.

Example:

Replace SP evaporator fan motor with ECM fan motor for cooler

*Unit kWh Savings per Year = (93 - 30)/1000 * 0.9 * 1 * (1 + 1/(0.98 * 2.5)) * 8766 * 1 = 700.0*

*Unit Peak kW Savings = (93 - 30)/1000 * 0.9 * 1 * (1 + 1/(0.98 * 2.5)) * 1 * 0.9 = 0.07*

Deemed Input Tables:

Table 1. Variables for HE Evaporator Fan Motor (ref. 3)

Motor Category	Weighting Percentage (population)[1]	Motor Output Watts	SP Efficiency	SP Input Watts	PSC Efficiency	PSC Input Watts	ECM Efficiency	ECM Input Watts
1-14 watts (Using 9 watt as industry average)	91%	9	18%	50	41%	22	66%	14
16-23 watts (Using 19.5 watt as industry average)	3%	19.5	21%	93	41%	48	66%	30
1/20 HP (~37 watts)	6%	37	26%	142	41%	90	66%	56

References:

1. US DOE Publication #46230-00, "Energy Savings Potential for Commercial Refrigeration Equipment", 1996, Arthur C. Little, Inc

http://www.scribd.com/doc/13260953/Energy-Savings-Potential-for-Commercial-Refrigeration-Equipment

2. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-103 to 4-106.

3. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Grocery Display Case ECM, FY2010, V2. Accessed from RTF website: <http://www.nwcouncil.org/rtf/measures/Default.asp on July 30, 2010>

4. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.

Documentation Revision History:

Version	Description	Author	Date
1	New measure	FES	8/20/2012
1.1	Minor revisions, changed name, corrected required inputs, removed qty from algorithms, changed hours from 8760 to 8766 to be consistent with other measures, removed New Construction and Replace on Fail from action types since as of 2009 federal standard requires ECM motors for evaporator fan motors < 1 HP and < 460V, changed measure description, replaced "cooler" with "refrigerator", removed reference 5 (applied to new construction)	JP	2/8/2013
1.2	Corrected Required Inputs	JP	3/29/2014

Commercial Beverage Machine Controls

Version No. 4.1

Measure Overview

Description: Installation of automatic shutoff control on refrigerated vending machines. Controls must include a passive infrared sensor to shut off lighting and compressor. Controls must be capable of periodically powering up the machine to maintain product temperature and provide compressor protection.

Actions: Replace Working (addition to working equipment)
Target Market Segments: Commercial
Target End Uses: Plug Loads

Applicable to: Commercial facilities with vending machines

Algorithms (Ref. 1)

Unit kWh Savings per Year = Wbase / 1000 x Hours x SavingsFactor

Unit Peak kW Savings = Unit kWh Savings per Year / Hours x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 5 (Ref. 3)

Unit Participant Incremental Cost = $180 (Ref. 4)

Where:

Wbase = 400 W; connected Wattage of the controlled equipment (Ref. 2)

Hours = 8,766 (average hours per year)

SavingsFactor = 46% (Ref. 2)

CF = 0.27 (Ref. 5)

Required from Customer/Contractor: n/a

Example:

A customer installed Vending Miser controls on their cold beverage vending machine.

Unit kWh Savings per Year = 400W / 1000 x (8,766 hours) x 46% = 1,613 kWh

Unit Peak kW Savings = 1,613 kWh / 8,766 hours x 0.27 = 0.050 kW

Notes:

There are no energy code requirements for this technology

References:

1. Energy and demand savings from Illinois Statewide Technical Resource Manual, pages 279-281.

2. USA Technologies Energy Management Product Sheets, July 2006; cited September 2009.

http://www.usatech.com/energy_management/energy_productsheets.php

*The SavingsFactor value is supported by the Focus on Energy's Deemed Savings Evaluation Report 2010, which references several studies in their defense of the figure.

3. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008

4. 2005 Database for Energy Efficiency Resources (DEER) Update Study Final Report - Residential and Commercial Non-Weather Sensitive Measures

5. Northwest Power and Conservation Council, 2001. Accessed 1/4/13.

www.nwcouncil.org/rtf/supportingdata/VendingMiser.XLS

Documentation Revision History:

Version / Description	Author	Date
1. Original from Nexant with extraneous tabs hidden	Nexant	
2. Reformatted	Joe Plummer, DER	
2.1 Changed action from New Construction to Replace Working	Joe Plummer, DER	
3. Added algorithm per the IL TRM	Franklin Energy Services	7/23/2012
3.1 Adjusted savings; increased kWh and eliminated kW savings	Franklin Energy Services	7/23/2012
3.2 Added example	Franklin Energy Services	7/23/2012
3.3 Revised Product Description	Franklin Energy Services	7/23/2012
4. Updated the CF to 0.27 per Reference 5	Franklin Energy Services	1/4/2013

4.1 Changed Action from Retrofit to Replace Working	JP	4/3/2013
4.1 Changed Target End Use from Specialty to Plug loads	JP	4/3/2013
4.1 Changed annual hours from 8,760 to 8,766 for consistency with other measures	JP	4/3/2013

Commercial Food Service - Electric Oven and Range

Version No. 4.1

Measure Overview

Description: This measure includes replacement of failed or working electric ovens and ranges with new high efficiency ovens and ranges. May also include new construction if facility does not have gas service.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x Rapid_Cook_Factor x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = (kW_Base - kW_EE) x CF x Rapid_Cook_Factor x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = 0 (heating effects are negligible)

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 4)

Unit Participant Incremental Cost = See Table 1

Where:

kW_EE = Deemed wattage (kW per unit) for high-efficiency cooking equipment meeting minimum efficiency standards

kW_Base = Deemed corresponding wattage (kW per unit) of baseline cooking technology calculated as kW_EE*New_Tech_Eff÷Base_Tech_Eff from Table 1 below

Rapid_Cook_Factor = Deemed increased savings resulting from increased throughput or reduced cooking times associated with advanced cooking technology

Hrs = Deemed annual operating hours by building type per Table 3

HVAC_cooling_kWhsavings_factor = Deemed cooling system energy savings factor resulting from efficient cooking per Table 2

CF = Deemed coincident demand factor based on cooking establishment type per Table 3.

HVAC_cooling_kWsavings_factor = Deemed cooling system demand savings factor resulting from efficient cooking per Table 2 below

Required from Customer/Contractor: Building type, heating only or heating and cooling, and new equipment type.

Example:

A high school cafeteria installed a new high efficiency flashbake oven.

Unit kWh Savings per Year = (1.24 kW - 0.91 kW) x 2,282 hrs x 1.67 x 1.03 = 1,295 kWh

Unit Peak kW Savings = (1.24 kW - 0.91 kW) x 39% x 1.67 x 1.04 = 0.224 kW

Deemed Input Tables:

Table 1: Pre- and Post-retrofit Equipment Parameters (Ref. 3, 5, 6)

Baseline Equipment	Efficient Equipment	kW_Base	kW_EE	Baseline Product Efficiency	Efficient Product Efficiency	Rapid Cook Factor	Incremental Cost (Ref. 5)
Full-size Range w/Std. Oven	Efficient Range w/Convection Oven	11.10	8.14	55.0%	75.0%	1.25	$3,000
Standard Oven	Flashbake Oven	1.24	0.91	55.0%	75.0%	1.67	$3,600
Standard Oven	Convection / Microwave Oven	1.28	0.80	50.0%	80.0%	1.25	$2,200
Standard Range	Induction Cooktop	5.10	4.14	65.0%	80.0%	1.00	$2,800

Table 2: HVAC Interactive Factors (Ref. 1)

HVAC system	HVAC Cooling kWh Savings Factor	HVAC cooling kW Savings Factor
Heating only	1.00	1.00
Heating and cooling	1.03	1.04

Table 3: Deemed Coincident Peak Demand Factors and Annual Operating Hours by Building Type (Ref. 2)

Building Type	CF	Hrs
Fast Food Limited Menu	32%	1,604
Fast Food Expanded Menu	41%	1,822
Pizza	46%	2,851
Full Service Limited Menu	51%	2,049
Full Service Expanded Menu	36%	1,731
Cafeteria	39%	2,282

Notes:

The following technologies have been removed from Table 1 because they now have their own measure: *Fryer, Griddle, Convection Oven and Steamer*

References:

1. HVAC Interactive Factors developed based on the HVAC Interaction Factor extracted from the Arkansas Food Service Deemed Savings table

2. Hours, CF taken from Project on Restaurant Energy Performance-End-Use Monitoring and Analysis, Appendixes I and II, Claar, et. al., May 1985

3. Food Service Technology Assessment Report, Fisher-Nickel, kW_EE is productivity enhancement adjusted

4. Measure life for similar food service equipment, 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

5. Incremental costs adopted from utility assumptions based on reasonable comparison against information in reference 3, above, and manufacturer Web sites

6. MN Utility Product Technical Assumption sheets provided for 2008 MN Deemed Savings project

Documentation Revision History:

Version / Description	Author	Date
2. Original from Nexant with extraneous tabs hidden	Nexant	
3. Added some clarifying notes	JP	
3.1 Modified Hrs description to reflect that operating hours will be deemed	JP	3/21/2012
3.2 Removed food warmers because baseline and efficient product efficiencies were identical. Original Nexant specs also did not show any savings.	JP	3/26/2012
4. Removed measures per note above and reformatted	Franklin Energy Services	8/29/2012
4.1 Changed measure name, changed description	JP	2/8/2013

Commercial Food Service – ENERGY STAR Electric Combination Oven

Version No. 2.1

Measure Overview

Description:

This measure includes the replacement of an electric combination oven with an ENERGY STAR electric combination oven, or installation of an ENERGY STAR combination oven in new construction.

ENERGY STAR combination ovens incorporate timesaving features via sophisticated control packages.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = (Eday_base - Eday_prop) x Days

Unit Peak kW Savings = Unit kWh Savings per Year / (OpHrs x Days) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $3,824 (Ref. 2)

Where:

Eday_base (kWh/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (kWh/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

LBFood = 200 lbs/day; Pounds of food cooked per day (Ref. 2)

Efood = 0.0732 kWh/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 44%; Heavy load cooking energy efficiency (Ref. 4)

Eff_prop = 65.5% (Ref. 6)

IdleRate_base = 7.5 kW; Idle Energy Rate (Ref. 2)

IdleRate_prop = 2.4 kW; (Ref. 7)

OpHrs = 8 hrs/day; Daily operating hours (Ref. 5)

PC_base = 80 lbs/hr; Production Capacity (Ref. 2)

PC_prop = 100 lbs/hr (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 3.00 kWh; Preheat energy (Ref. 2)

E_pre_prop = 1.50 kWh (Ref. 2)

Days = See Table 1

CF = 0.9 (Ref. 2)

Required from Customer/Contractor: building type

Example:

A cafeteria in a large office building installed a new ENERGY STAR electric combination oven.

Eday_base (kWh/day) = (200 lbs/day) x (0. 0732 kWh/lb) / (44%) + [7.5 kW x (8 hrs/day - (200 lbs/day / 80 lbs/hr) - (15 min / 60 min/hr))] + 3.00 kWh/day = 75.6 kWh/day

Eday_prop (kWh/day) = (200 lbs/day) x (0. 0732 kWh/lb) / (65.5%) + [2.4 kW x (8 hrs/day - (200 lbs/day / 100 lbs/hr) - (15 min / 60 min/hr))] + 1.50 kWh/day = 37.7 kWh/day

Unit kWh Savings per Year = (75.6 kWh/day - 43.2 kWh/day) x 250 days/yr = 9,475 kWh

Unit Peak kW Savings = 9,475 kWh / (8 hr/day x 250 days/yr) x 0.9 = 4.264 kW

Deemed Input Tables:

Table 1: Operation Hours by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
Other Commercial	250

Methodology and Assumptions:

Table 2: ENERGY STAR Electric Combination Oven Criteria (Ref. 6,7)

Operation	Idle Rate, kW	Cooking-Energy Efficiency, %
Steam Mode	≤ 0.133P+0.6400	≥ 55
Convection Mode	≤ 0.080P+0.4989	≥ 76
Average (assuming 6-pan unit)	**2.4**	**65.5**

Notes:

There is no code requirement for this technology.

References:

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

2. *Commercial Combination Ovens,* Food Service Equipment Workpaper PGECOFST100 R1, PG&E. June 1, 2009.

3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

4. 2008 Database for Energy-Efficient Resources Version 2008.2.05 December 16, 2008; ***www.deeresources.com*** / DEER 2005 / **DEER 2005 Version Reports and Notifications/** DEER 2005 Version 2.01 Enhancements and Notifications

5. *Technology Assessment: Ovens,* Food Service Technology Center, 2002. Page 7-23. http://www.fishnick.com/equipment/techassessment/7_ovens.pdf

6. Average of steam and convection cooking efficiencies listed in ENERGY STAR Commercial Ovens Key Product Criteria, Version 2.1. http://www.energystar.gov/index.cfm?c=ovens.pr_crit_comm_ovens. Accessed 7/9/14.

7. Sum of steam and convection oven idle rates (summed because they can be used simultaneously), assuming 6-pans to be conservative, rounded to nearest tenth. Ref. 6.

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/27/2012
2. Updated to include ENERGY STAR version 2.1 specification	Franklin Energy Services	07/31/2014
2.1 Updated description to include new construction, changed 365 to 365.25 for consistency with other measures, put Table 2 in Methodology & Assumptions section	JP	7/31/2014

Commercial Food Service – ENERGY STAR Electric Convection Oven

Version No. 1.2

Measure Overview

Description:

This measure includes installation of high efficiency ENERGY STAR electric convection ovens instead of standard efficiency units.

Energy efficient commercial electric ovens reduce energy consumption primarily through sophisticated control packages.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = (Eday_base - Eday_prop) x Days

Unit Peak kW Savings = Unit kWh Savings per Year / (OpHrs x Days) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $1,682 (Ref. 2)

Where:

Eday_base (kWh/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (kWh/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

LBFood = 100 lbs/day; Pounds of food cooked per day (Ref. 2)

Efood = 0.0732 kWh/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 65%; Heavy load cooking energy efficiency (Ref. 2)

Eff_prop = 70% (Ref. 4)

IdleRate_base = 2.00 kW; Idle Energy Rate (Ref. 2)

IdleRate_prop = 1.6 kW; (Ref. 4)

OpHrs = 8 hrs/day; Daily operating hours (Ref. 5)

PC_base = 70 lbs/hr; Production Capacity (Ref. 2)

PC_prop = 80 lbs/hr (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 1.50 kWh; Preheat energy (Ref. 2)

E_pre_prop = 1.00 kWh (Ref. 2)

Days = See Table 1

CF = 0.9 (Ref. 6)

Required from Customer/Contractor: building type

Example:

A fast food restaurant installed a new ENERGY STAR Electric Convection Oven

Eday_base (kWh/day) = (100 lbs/day) x (0. 0732 kWh/lb) / (65%) + [2.00 kW x (8 hrs/day - (100 lbs/day / 70 lbs/hr) - (15 min / 60 min/hr))] + 1.50 kWh/day = 25.4 kWh/day

Eday_prop (kWh/day) = (100 lbs/day) x (0. 0732 kWh/lb) / (70%) + [1.60 kW x (8 hrs/day - (100 lbs/day / 80 lbs/hr) - (15 min / 60 min/hr))] + 1.00 kWh/day = 21.9 kWh/day

Unit kWh Savings per Year = (25.4 kWh/day - 21.9 kWh/day) x 365 days/yr = 1,278 kWh

Unit Peak kW Savings = 1,278 kWh / (8 hr/day x 365 days/yr) x 0.9 = 0.394 kW

Deemed Input Tables:

Table 1: Operation Hours by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Notes:

There is no code requirement for this technology.

ENERGY STAR requires that Full Size Electric Ovens have a cooking energy efficiency ≥ 70% and an idle energy rate ≤ 1.6 kW (Ref. 4)

ENERGY STAR requires that Half Size Electric Ovens have a cooking energy efficiency ≥ 70% and an idle energy rate ≤ 1.0 kW (Ref. 4)

References:

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

2. *Commercial Convection Ovens,* Food Service Equipment Workpaper PGEOFST101 R1, PG&E. June 1, 2009.

3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

4. *Commercial Ovens Key Product Criteria,* http://www.energystar.gov/index.cfm?c=ovens.pr_crit_comm_ovens. Accessed August, 15, 2012.

5. *Technology Assessment: Ovens,* Food Service Technology Center, 2002. Page 7-22. http://www.fishnick.com/equipment/techassessment/7_ovens.pdf

6. 2004-05 Database for Energy Efficiency Resources (DEER) Update Study Final Report, pp. 3-15 to 3-18. http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/14/2012
1.1 Renamed measure	JP	2/8/2013
1.2 Corrected preheat energy labels	JP	10/29/13

Commercial Food Service – ENERGY STAR Electric Fryer

Version No. 1.2

Measure Overview

Description: This measure includes installation of high efficiency ENERGY STAR electric fryers instead of standard efficiency units. Energy efficient commercial electric fryers reduce energy consumption primarily through the application of advanced controls and insulation.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = (Eday_base - Eday_prop) x Days

Unit Peak kW Savings = Unit kWh Savings per Year / (OpHrs x Days) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $1,344 (Ref. 2)

Where:

Eday_base (kWh/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (kWh/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

LBFood = 150 lbs/day; Pounds of food cooked per day (Ref. 2)

Efood = 0.167 kWh/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 75%; Heavy load cooking energy efficiency % (Ref. 2)

Eff_prop = 80% (Ref. 2)

IdleRate_base = 1.05 kW; Idle Energy Rate (Ref. 2)

IdleRate_prop = 1.00 kW (Ref. 2)

OpHrs = 12 hrs/day; Daily operating hours (Ref. 6)

PC_base = 65 lbs/hr; Production Capacity (Ref. 2)

PC_prop = 70 lbs/hr (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 2.3 kWh/day; Preheat energy (Ref. 2)

E_pre_prop = 1.7 kWh/day (Ref. 2)

Days = See Table 1

CF = 0.9 (Ref. 5)

Required from Customer/Contractor: building type

Example:

A fast food restaurant installed a new ENERGY STAR Electric Fryer

Eday_base (kWh/day) = (150 lbs/day) x (0.167 kWh/lb) / (75%) + [1.05 kW x (12 hr/day - (150 lbs/day / 65 lb/hr) - (15 min / 60 min/hr))] + 2.3 kWh/day = 45.6 kWh/day

Eday_prop (kWh/day) = (150 lbs/day) x (0.167 kWh/lb) / (80%) + [1.00 kW x (12 hr/day - (150 lbs/day / 70 lb/hr) - (15 min / 60 min/hr))] + 1.7 kWh/day = 42.6 kWh/day

Unit kWh Savings per Year = (45.6 kWh/day - 42.6 kWh/day) x 365 days/yr = 1,095 kWh

Unit Peak kW Savings = 1,095 kWh / (12 hr/day x 365 days/yr) x 0.9 = 0.225 kW

Deemed Input Tables:

Table 2: Operation Hours by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Notes:

There is no code requirement for this technology.

ENERGY STAR requires Standard Open Deep-Fat Electric Fryers have a heavy-load cooking efficiency ≥ 80% and an idle energy rate ≤ 1,000 Watts (Ref. 4)

ENERGY STAR requires Large Vat Open Deep-Fat Electric Fryers have a heavy-load cooking efficiency ≥ 80% and an idle energy rate ≤ 1,100 Watts (Ref. 4)

References:

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

2. *Commercial Fryer,* Food Service Equipment Workpaper PGEOFST102 R1, PG&E. June 1, 2009.

3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

4. *Commercial Fryers Key Product Criteria,* http://www.energystar.gov/index.cfm?c=fryers.pr_crit_fryers. Accessed August, 15, 2012.

5. 2004-05 Database for Energy Efficiency Resources (DEER) Update Study Final Report, pp. 3-15 to 3-18. http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf

6. *Technology Assessment: Fryer,* Food Service Technology Center, 2002. Page 2-21. http://www.fishnick.com/equipment/techassessment/2_fryers.pdf

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/14/2012
1.1 Changed measure name	JP	2/8/2013
1.2 Corrected preheat energy labels	JP	10/30/13

Commercial Food Service – ENERGY STAR Electric Griddle

Version No. 1.2

Measure Overview

Description: This measure includes installation of high efficiency ENERGY STAR electric griddles instead of standard efficiency units. Energy efficient commercial electric griddles reduce energy consumption primarily through application of advanced controls and improved temperature uniformity.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = (Eday_base - Eday_prop) x Days

Unit Peak kW Savings = Unit kWh Savings per Year / (OpHrs x Days) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $2,162 (Ref. 2)

Where:

Eday_base (kWh/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (kWh/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

LBFood = 100 lbs/day; Pounds of food cooked per day (Ref. 2)

Efood = 0.139 kWh/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 65%; Heavy load cooking energy efficiency (Ref. 2)

Eff_prop = 70% (Ref. 2)

IdleRate_base = 2.50 kW; Idle Energy Rate (Ref. 2)

IdleRate_prop = 2.13 kW (Ref. 4); Assumes a 3' x 2' griddle size and a Tier 1 idle rate

OpHrs = 12 hrs/day; Daily operating hours (Ref. 5)

PC_base = 35 lbs/hr; Production Capacity (Ref. 2)

PC_prop = 40 lbs/hr (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 4.00 kWh; Preheat energy (Ref. 2)

E_pre_prop = 2.00 kWh; (Ref. 2)

Days = See Table 1

CF = 0.9 (Ref. 6)

Required from Customer/Contractor: building type

Example:

A hospital installed a new ENERGY STAR Electric Griddle in its kitchen

Eday_base (kWh/day) = (100 lbs/day) x (0.139 kWh/lb) / (65%) + [2.5 kW x (12 hr/day - (100 lbs/day / 35 lb/hr) - (15 min / 60 min/hr))] + 4.00 kWh = 47.6 kWh/day

Eday_base (kWh/day) = (100 lbs/day) x (0.139 kWh/lb) / (70%) + [2.13 kW x (12 hr/day - (100 lbs/day / 40 lb/hr) - (15 min / 60 min/hr))] + 2.00 kWh = 41.6 kWh/day

Unit kWh Savings per Year = (47.6 kWh/day - 41.6 kWh/day) x 365 days/yr = 2,190 kWh

Unit Peak kW Savings = 2,190 kWh / (12 hrs/day x 365 days/yr) x 0.90 = 0.450 kW

Deemed Input Tables:

Table 1: Operation Hours by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Methodology and Assumptions:

Savings assumes a 3' x 2' griddle size and a Tier 1 idle rate.

Notes:

There is no code requirement for this technology.

ENERGY STAR requires that Tier 1 Electric Griddles have a cooking energy efficiency ≥ 70% and a normalized idle energy rate ≤ 355 Watts per ft^2 (Ref. 4)

ENERGY STAR requires that Tier 2 Electric Griddles have a cooking energy efficiency ≥ 70% and a normalized idle energy rate ≤ 320 Watts per ft^2 (Ref. 4)

References:

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

2. *Commercial Griddles,* Food Service Equipment Workpaper PGECOFST103 R1, PG&E. June 1, 2009.

3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

4. *Commercial Griddles Key Product Criteria,* http://www.energystar.gov/index.cfm?c=griddles.pr_crit_comm_griddles. Accessed August, 15, 2012.

5. *Technology Assessment: Griddles,* Food Service Technology Center, 2002. Page 3-22. http://www.fishnick.com/equipment/techassessment/3_griddles.pdf

6. 2004-05 Database for Energy Efficiency Resources (DEER) Update Study Final Report, pp. 3-15 to 3-18. http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/14/2012
1.1 Renamed measure	JP	2/8/2013
1.2 Fixed preheat energy labels	JP	10/30/13

Commercial Food Service – ENERGY STAR Electric Hot Food Holding Cabinet

Version No. 1.1

Measure Overview

Description:

This measure includes installation of high efficiency ENERGY STAR electric hot food holding cabinets (HFHCs) instead of standard efficiency units. Energy efficient commercial

HFHCs reduce energy consumption primarily through better insulation, magnetic door electric gaskets, auto-door closures, or Dutch doors.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = (kW_base - kW_prop) x Hours x Days

Unit Peak kW Savings = (kW_base - kW_prop) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = See Table 1 (Ref. 2)

Where:

kW_base = Wattage of baseline unit. See Table 1. (Ref. 6)

kW_prop = Wattage of ENERGY STAR unit. See Table 1 (Ref. 4)

Hours = 15 hrs/day (Ref. 7)

Days = See Table 2

CF = 0.9 (Ref. 5)

Required from Customer/Contractor: building type, cabinet volume

Example:

A sit-down food restaurant installed a new full-size ENERGY STAR Electric HFHC

Unit kWh Savings per Year = (2.0 kW - 0.294 kW) x 15 hrs/day x 365 days/yr = 9,340 kWh

Unit Peak kW Savings = (2.0 kW - 0.294 kW) x 0.9 = 1.54 kW

Deemed Input Tables:

Table 1: Hot Food Holding Cabinet Performance Characteristics

Size	Volume (ft^3)	kW_base	kW_prop	Incremental Cost
Full-Size	20	2.000	0.294	$1,891
3/4-Size	12	1.200	0.258	$707
Half-Size	8	0.800	0.172	$1,497

Table 2: Operation Hours by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Methodology and Assumptions:

The baseline energy usage is assumed to be 100 W/ft^2 based on the FSTC Life Cycle Cost Calculator

Notes:

There is no code requirement for this technology.

ENERGY STAR requires that Electric HFHCs (28 $ft^3 \leq$ Volume) have an idle rate defined by: Watts $\leq$ 3.8 x Volume (ft^3) + 203.5

ENERGY STAR requires that Electric HFHCs (13 $ft^3 \leq$ Volume < 28 ft^3) have an idle rate defined by: Watts $\leq$ 2.0 x Volume (ft^3) + 254.0

ENERGY STAR requires that Electric HFHCs (Volume $\leq$ 13 ft^3) have an idle rate defined by: Watts $\leq$ 21.5 x Volume (ft^3)

References:

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.
2. *Insulated Holding Cabinet,* Food Service Equipment Workpaper PGECOFST105 R1, PG&E. June 1, 2009.
3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
4. *Commercial Hot Food Holding Cabinets Key Product Criteria,* http://www.energystar.gov/index.cfm?c=hfhc.pr_crit_hfhc. Accessed 8/24/12.
6. 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study Final Report, pp. 3-15 to 3-18. http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf
7. *Hot-Food Holding Cabinet Life-Cycle Cost Calculator*, Food Service Technology Center, http://www.fishnick.com/saveenergy/tools/calculators/holdcabcalc.php. Accessed on 8/27/12.

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/24/2012
1.1 Update sizes	Franklin Energy Services	8/27/2012

Commercial Food Service – ENERGY STAR Electric Steamer

Version No. 1.0

Measure Overview

Description: This measure includes replacement of commercial electric steamers with new 5 or 6-pan ENERGY STAR electric steamers.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = (Eday_base - Eday_prop) x Days

Unit Peak kW Savings = Unit kWh Savings per Year / (OpHrs x Days) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $2,490 (Ref. 2)

Where:

Eday_base (kWh/day) = LBFood x Efood / Eff_base + (IdleRate_base + Res_Rate_base) x (OpHrs - LBFood / PC_base - T_pre / 60) + E_pre_base

Eday_prop (kWh/day) = LBFood x Efood / Eff_prop + (IdleRate_prop + Res_Rate_prop) x (OpHrs - LBFood / PC_prop - T_pre / 60) + E_pre_prop

LBFood = See Table 1; Pounds of food cooked per day (Ref. 2)

Efood = 0.0732 kWh/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 26%; Heavy load cooking energy efficiency (Ref. 2)

Eff_prop = 50% (Ref. 2)

IdleRate_base = See Table 1; Idle Energy Rate (Ref. 2)

IdleRate_prop = See Table 1; (Ref. 2)

OpHrs = 12 hrs/day; Daily operating hours (Ref. 2)

PC_base = See Table 1; Production Capacity (Ref. 2)

PC_prop = See Table 1 (Ref. 2)

Res_Rate_base = 1.910 kW; Residual Energy Rate (Ref. 2)

Res_Rate_prop = 0.120 kW; Residual Energy Rate (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre = 1.50 kWh; Preheat energy (Ref. 2)

Days = See Table 1

CF = 0.9 (Ref. 1)

Required from Customer/Contractor: building type, number of pans

Example:

A health clinic cafeteria installed a new 6-pan ENERGY STAR Electric Steam Cooker

Eday_base (kWh/day) = (192 lbs/day) x (0. 0308 kWh/lb) / (26%) + (2.00 kW + 1.91 kW) x (12 hrs/day - (192 lbs/day / 120 lbs/hr) - (15 min / 60 min/hr)) + 1.50 kWh/day = 63.9 kWh/day

Eday_prop (kWh/day) = (192 lbs/day) x (0. 0308 kWh/lb) / (50%) + (0.80 kW + 0.120 kW) x (12 hrs/day - (192 lbs/day / 100 lbs/hr) - (15 min / 60 min/hr)) + 1.50 kWh/day = 22.4 kWh/day

Unit kWh Savings per Year = (63.9 kWh/day - 22.4 kWh/day) x 365 days/yr = 15,147 kWh

Unit Peak kW Savings = 15,147 kWh / (12 hr/day x 365 days/yr) x 0.9 = 3.112 kW

Deemed Input Tables:

Table 1: Steamer Characteristics

	3-Pan Steamer	4-Pan Steamer	5-Pan Steamer	6-Pan Steamer
LBFood (lbs/day)	100	128	160	192
Efood (kWh/lb)	0.0308	0.0308	0.0308	0.0308
Eff_base (%)	26%	26%	26%	26%
Eff_prop (%)	50%	50%	50%	50%
IdleRate_base (kW)	1.000	1.325	1.675	2.000
IdleRate_prop (kW)	0.400	0.530	0.670	0.800
OpHrs (hrs/day)	14	14	14	14
PC_base (lbs/hr)	70	87	103	120
PC_prop (lbs/hr)	50	67	83	100
Res_Rate_base (kW)	1.910	1.910	1.910	1.910
Res_Rate_prop (kW)	0.120	0.120	0.120	0.120
T_pre (minutes)	15	15	15	15
E_pre	1.5	1.5	1.5	1.5

Table 2: Operation Hours by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Notes:

There is no code requirement for this technology.

ENERGY STAR requires that Electric Steam Cookers have the following efficiencies (Ref. 4):

Pan Capacity	Cooking Energy Efficiency	Idle Rate (Watts)
3-Pan	50%	400
4-Pan	50%	530
5-Pan	50%	670
6-Pan	50%	800

References:

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

2. *Commercial Steam Cookers,* Food Service Equipment Workpaper PGECOFST104 R1, PG&E. June 1, 2009.

3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

4. *Commercial Steam Cookers Key Product Criteria,* http://www.energystar.gov/index.cfm?c=steamcookers.pr_crit_steamcookers. Accessed August, 27, 2012.

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/27/2012

Commercial Hot Water – Electric Water Heater

Version No. 6.6

Measure Overview

Description: This measure includes replacement of failed or working electric resistance water heaters in existing commercial facilities with high efficiency units, as well as installation of high efficiency electric water heaters in new facilities.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: DHW

Applicable to: Electric resistance storage water heaters with tank sizes greater than or equal to 20 gallons installed in commercial applications.

Algorithms

Unit kWh Savings per Year = EnergyToHeatWater x (1 / Eff_Base - 1 / Eff_High) / ConversionFactor

Unit Peak kW Savings = Unit kWh Savings / 8,766 hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years): see Table 4

Unit Participant Incremental Cost: see Table 5

Where:

EnergyToHeatWater = SpecificHeat x Density x GalPer1000SqftPerDay x Area/1000 x DaysPerYear x (Tset - Tcold)

SpecificHeat = 1.0 btu / (lb x °F)

Density = 8.34 lbs / gal

GalPer1000SqftPerDay = Deemed gallons per 1,000 square foot per day based on building type per Table 2

DaysPerYear = Days per year of operation per Table 2

Area = Minimum of:

- Floor area served by the water heater in ft^2, provided by customer/contractor
- Tank Size / (Min Storage Capacity per 1,000 sq ft, see Table 2) x 1000, the maximum floor area that could be served by the water heater in ft^2 based on tank size
- (Input kW * 3.412) / (Min Heating Capacity per 1,000 sq ft, see Table 2) x 1000, the maximum floor area that could be served by the water heater in ft^2 based on heating capacity

Tset = 140 °F (Ref. 8)

Tcold = Average groundwater temperature per Table 1

Eff_Base = Efficiency of standard water heater, expressed as Energy Factor (EF) per Table 3.

Eff_High = Efficiency of efficient water heater, expressed as Energy Factor (EF).

ConversionFactor = 3,412 Btu/kWh: electric water heaters

Required from Customer/Contractor: Confirmation of electric resistance storage water heater, input kW), efficiency of new water heater, tank size in gallons, building type, floor area served by water heater in square feet, project location (county)

Example:

A 1,300 ft² fast food restaurant in Zone 2 installed a new 60-gallon, 12 kW electric storage water heater with an EF of 0.95

Max area based on tank size = 60/38.9 x 1000 = 1,542 ft²
Max area based on heating capacity = (12 x 3.412)/34.4 x 1000 = 1,190 ft²

Area = minimum (1300, 1542, 1190) = 1,190 ft²

EnergyToHeatWater = 1 x 8.34 x 549.2 x 1190/1000 x (365.25 day/yr) x (140 - 49.1) = 180,966,276 Btu/yr

Eff_Base = 0.97 – (0.00132 x 60) = 0.89

Unit kWh Savings per Year = 180,966,276 x (1/0.89 - 1/.95) /3,412= 3,764 kWh

Unit Peak kW Savings = 3,764 / 8,766 = 0.429 kW

Deemed Input Tables:

Table 1: Average groundwater temperatures (Ref. 1)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3

Table 2: Deemed Annual Hot Water Use by Building Type, Minimum Storage Capacity and Heating Capacity (Ref. 2)

Building Type	Days Per Year	Annual Hot Water Load (Gal per 1,000 Sqft Per Day)	Minimum Storage Capacity (Gal per 1,000 Sqft)	Minimum Heating Capacity (kBtu/hr per 1,000 Sq Ft)
Small Office	250	2.3	0.7	0.6
Large Office	250	2.3	0.7	0.6
Fast Food Restaurant	365.25	549.2	38.9	34.4
Sit-Down Restaurant	365.25	816.0	36.0	31.9
Retail	365.25	2.0	0.6	0.6
Grocery	365.25	2.2	0.7	0.6
Warehouse	250	1.0	0.3	0.3
Elementary School	200	5.7	4.6	4.0
Jr. High/High School/College	200	17.1	7.6	6.7
Health	365.25	342.0	21.4	27.8
Motel	365.25	100.0	23.9	21.1
Hotel	365.25	30.8	8.8	7.8
Other Commercial	250	0.7	0.2	0.2

Table 3: Deemed baseline efficiency based on ASHRAE 90.1-2004, as amended by MN Commercial Energy Code (Ref. 3)

Equipment Type	Input Power	Tank Size	Minimum Efficiency	Efficiency Metric
Electric Resistance Storage Water Heaters	≤ 12 kW, > 12 kW	≥ 20 gal	0.97 - (0.00132 x gal)	Energy Factor

Table 4: Measure Lifetime by Type (Ref. 4)

Equipment Type	Lifetime (years)
Electric Resistance Storage Water Heaters	13

Table 5: Incremental Cost by Type

Equipment Type	Input kW	Incremental Cost	
Electric Resistance Storage Water Heaters	≤ 12 kW	$104.00	(Ref. 5)
	> 12 kW	$1,350.00	(Ref. 6)

Notes:

Current water heater efficiency standards are given in Table 3. No change to standards in ASHRAE 90.1-2010 (under consideration for adoption in Minnesota Commercial Energy Code.)

References:

1. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules*

http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

2. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

3. Minnesota Commercial Energy Code, Minn. Rules ch. 1323.0780 Table 7.8, Performance Requirements for Water Heating Equipment.

4. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008

5. Values are from DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Tables 8.2.13-14, 8.2.16

http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf

*The values are interpreted with explanation in the "Cost Info" tab of this worksheet.

6. ActOnEnergy Technical Resource Manual, Standard Measures, 5/31/2011. Pages 278, 284 and 286.

7. "Lower Water Heating Temperature for Energy Savings," Department of Energy website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Accessed 7/26/12.

8. "To minimize the growth of Legionella in the system, domestic hot water should be stored at a minimum of 60°C (140°F) " http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_7.html#5. Section III, Chapter 7; V.C.3.a

Documentation Revision History:

Version / Description	Author	Date
4. Original from Nexant with extraneous tabs hidden	Nexant	
5. Updated baseline efficiencies to reflect 2009 MN Commercial Energy Code; updated supply water temperature per Eno Scientific groundwater temp map	JP	
5.1 Corrected formula to include square footage	JP	
5.2 Corrected deemed baseline efficiency for gas instantaneous water heaters	JP	
5.3 Changed label "Gal Per SqFt" in Table 2 to "Gal Per 1,000 SqFt", corrected error in algorithm to use Days Per Year from Table 2 instead of 365, corrected labeling error (changed EF_Efficient to Eff_High)	JP	
5.4 Changed water density from 8.35 to 8.34 to be consistent with	JP	

residential water heater spec		
5.5 Changed Eff_High description to reference efficient water heater; EF or thermal efficiency should be consistent with Eff_Base	SK	
6. Updated the groundwater temperatures	Franklin Energy Services	7/23/2012
6.1 Added electric water heater data and example	Franklin Energy Services	7/23/2012
6.2 Changed the measure lifetimes to reflect DEER EUL	Franklin Energy Services	7/23/2012
6.3 Updated incremental costs	Franklin Energy Services	7/23/2012
6.3 Changed hot water temp to 140 oF per OSHA guidelines for prevention of Legionnaire's contamination	Franklin Energy Services	3/20/2013
6.4 Added Replace Working to action types, changed title from Commercial Electric Water Heaters to Commercial Hot Water - Water Heater, changed Applicable To text, revised require inputs to work with gas or electric water heaters, changed 8760 to 8766 hours and 365 days to 365.25 to be consistent with other measures, changed example accordingly, changed descriptive information in header to apply to electric water heaters only	JP	3/22/2013
6.6 Removed heat pump water heaters until more research is available, added CenterPoint Energy method to adjust area if tank size or heating capacity is insufficient to meet hot water load, modified example accordingly, added > 12 kW resistance storage tanks to <= 12 kW minimum efficiency formula based on Minn. Comm. Energy Code amendments to ASHRAE 90.1-2004	JP	2/25/14

Commercial Hot Water - Faucet Aerator (1.5 gpm) with Electric Water Heater

Version No. 3.4

Measure Overview

Description: This measure includes replacing an existing faucet aerator with a low-flow aerator.

Actions: Replace Working
Target Market Segments: Commercial
Target End Uses: DHW

Applicable to: Commercial facilities with electric water heaters. Measure includes installation of 1.5 GPM aerators only.

Algorithms

Unit kWh Savings per Year = ((GPM_base - GPM_low) x L x NOPF x Days x DF / GPMfactor) x EPG

Unit Peak kW Savings = Unit kWh Savings per Year / 8,766 hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 1)

Unit Participant Incremental Cost = $6.70 (Ref. 6)

Where:

EPG = Density x Specific Heat x (Tfaucet - Tcold) / (ReEff x ConversionFactor)

NOPF = People / Faucets

GPM_base = 1.2 gpm (Ref. 2); Flow rate of existing 2.5 GPM aerator, adjusted for throttled flow uses

GPM_low = 0.94 gpm (Ref. 2); Flow rate of proposed 1.5 GPM aerator, adjusted for throttled flow uses

L = 9.85 min/person/day; Usage time (Ref. 2)

People = Provided by customer; Number of people in facility

Faucets = Provided by customer; Number of faucets in facility

DF = See Table 2; Drain Factor that accounts for uses that are volumetric in nature and aren't affected by low-flow aerators

GPM Factor = See Table 2; Factor accounts for differences in use between commercial and residential applications

Days = See Table 3; Days of operation

Specific Heat = 1.0 Btu / (lb x °F); Specific heat of water

Density = 8.34 lbs / gal; Density of water

Tfaucet = 90°F; Temperature of typical faucet usage (Ref. 2)

Tcold = Average groundwater temperature per Table 1 (Ref. 4)

ReEff = Recovery Efficiency = 98% (electric water heater) (Ref. 2)

Conversion Factor = 3,412 Btu/kWh (electric water heater)

Required from Customer/Contractor: confirmation of electric water heater, project location (county), number of people, number of faucets, bath or kitchen faucets.

Example:

Direct installation of a 1.5 GPM faucet aerator in a small office kitchen with electric water heat located in Zone 1. The office has 20 people and 5 faucets.

NOPF = 20 people / 5 faucets = 4.0

EPG = (8.34 lbg/gal) x (1.0 Btu/lb°F) x (90°F - 46.5°F) / (98% x 3,412 Btu/kWh) = 0.108 kWh/gal

Unit kWh Savings per Year = ((1.2 gpm - 0.94 gpm) x (9.85 min/person/day) x (4.0) x (250 days) x (75%)) / 1.0 x 0.108 kWh/gal = 207 kWh

Unit Peak kW Savings = 207 kWh / 8,766 hours = 0.023 kW

Deemed Input Tables:

Table 1: Average groundwater temperatures (Ref. 4)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3

Table 2: Faucet Characteristics (Ref. 2)

Application	DF	GPMfactor
Kitchen	75%	1.0
Bath	90%	2.5

Table 3: Deemed Annual Hot Water Use by Building Type (Ref. 7)

Building Type	Days Per Year
Small Office	250
Large Office	250
Fast Food Restaurant	365.25
Sit-Down Restaurant	365.25
Retail	365.25
Grocery	365.25
Warehouse	250
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Motel	365.25
Hotel	365.25
Other Commercial	250

Methodology and Assumptions:

Uses algorithms from IL TRM (Ref. 2)

(L), Usage time coincides with the middle of the range (6.74 min/per/day to 13.4 min/per/day) from multiple sources.

GPM_base is a representative baseline flow rate for kitchen and bathroom faucet aerators from mulitple sources.

GPM_low is an average retrofit flow rate for kitchen and bathroom faucet aerators from multiple sources. This accounts for all throttling and differences from rated flow rates.

Notes:

The current standard for kitchen and bathroom aerators is 2.2 GPM, effective 1/1/1994. (Ref. 5)

References:

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values. http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.

2. State of Illinois Energy Efficiency Technical Reference Manual, Page 132-139. July 18, 2012.

3. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates)* for the state of MN.
http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table

4. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules*
http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

5. Title 10, Code of Federal Regulations, Part 430 - Energy Conservation Program for Consumer Products, Subpart C - Energy and Water Conservation Standards and Their Effective Dates. January 1, 2010

6. 2008 Database for Energy-Efficient Resources, Cost Values and Summary Documentation (updated 6/2/2008 - NR linear fluorescent labor costs typo)
http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.

7. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer, DER	
2. Revised formatting and algorithms	Franklin Energy Services	7/27/2012
2. Update the measure life and measure cost	Franklin Energy Services	7/27/2012
3. Update the algorithm to IL TRM	Franklin Energy Services	8/27/2012
3.1 Update the Peak kW algorithm	Franklin Energy Services	8/28/2012
3.2 Changed Action from Direct Install to Replace Working, changed from 8760 to 8766 hours per year to be consistent with other measures, minor edits.	JP	3/13/2013
3.3 Changed “electric or gas water heater” to “confirmation of electric water heater” in Required Inputs	JP	11/25/13
3.4 Changed descriptive information to specify that measure is for customers with electric water heaters. Corrected example calculations.	JP	1/3/14

Commercial Hot Water - Pre-Rinse Sprayers (1.6 gpm) with Electric Water Heater

Version No. 2.6

Measure Overview

Description: This measure includes retrofit of working standard pre-rinse sprayers with low-flow, 1.6 gpm pre-rinse sprayers in commercial kitchen applications.

Actions: Replace Working
Target Market Segments: Commercial
Target End Uses: DHW

Applicable to: Commercial facilities with kitchens: restaurants, large office buildings, etc, with electric water heaters.

Algorithms

Unit kWh Savings per Year = EPG x WaterSaved / EF_electric / ConversionFactor

Unit Peak kW Savings = (Unit kWh Savings per Year) / 8,766 hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 5 (Ref. 1)

Unit Participant Incremental Cost = $100 (Ref. 3)

Where:

EPG = SpecificHeat x Density x (Tmix - Tcold)

WaterSaved = (Flow_base x Hours_base - Flow_eff x Hours_eff) x 60 min/hr x Days

SpecificHeat = 1.0 btu / (lb x °F)

Density = 8.34 lbs / gal

Flow_base = 2.23 gal/min (Ref. 1)

Flow_eff = 1.12 gal/min (Ref.1)

Hours_base = 0.44 hr/day (Ref. 1)

Hours_eff = 0.60 hr/day (Ref. 1)

Days = See Table 2

Tmix = 105 °F; spray water temperature (Ref. 1)

Tcold = Average groundwater temperature per Table 1 (Ref. 2)

EF_gas = 0.75 (Ref. 3)

EF_electric = 0.98 (Ref. 3)

ConversionFactor = 3,412 Btu/kWh (electric water heater) or 1,000,000 Btu/Dth (gas water heater)

Required from Customer/Contractor: Confirmation of electric water heater, building type, project location (county)

Example:

A direct install crew has installed a low-flow pre-rinse spray valve in a local sit-down restaurant kitchen located in Zone 2. The existing water heater is electric.

WaterSaved = (2.23 gal/min x 0.44 hr/day - 1.12 gal/min x 0.60 hr/day) x 60 min/day x 365.25 day/yr = 6776 gal/yr

EPG = (1 Btu/lb°F) x (8.34 lbs/gal) x (105°F - 49.1°F) = 466.2 Btu/gal

*Unit kWh Savings per Year = 466.2 Btu/gal * 6,776 gal/yr / 0.98 / (3,412 Btu/kWh) = 945 kWh/yr*

Unit Peak kW Savings = 945 kWh / 8,766 hours = 0.108 kW

Deemed Input Tables:

Table 1: Average groundwater temperatures (Ref. 2).

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3

Table 2: Deemed Annual Hot Water Use by Building Type (Ref. 6)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
Other Commercial	250

Methodology and Assumptions:

The following building types were considered not to apply to this measure: Small Office, Retail, Warehouse and Motel

Notes:

The current flow standard for Pre-Rinse Sprayers is 1.6 GPM (Ref. 4)

The Federal Energy Management Program (FEMP) requires the federal government purchase and install pre-rinse spray valves with 1.25 gpm in federal buildings. (Ref.7)

References:

1. IMPACT AND PROCESS EVALUATION FINAL REPORT for CALIFORNIA URBAN WATER CONSERVATION COUNCIL 2004-5 PRE-RINSE SPRAY VALVE INSTALLATION PROGRAM (PHASE 2)

2. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules*
http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

3. State of Illinois Energy Efficiency Technical Reference Manual, June 1st, 2012. Pages 109-113.

4. Title 10, Code of Federal Regulations, Part 431 - Energy Efficiency Program for Certain Commercial and Industrial Equipment, Subpart O - Commercial Prerinse Spray Valves. January 1, 2010.

5. No demand savings are claimed for this measure since there is insufficient peak coincident data.

6. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

7. FEMP Designated Product: Pre-Rinse Spray Valves, Purchasing Specification for Energy Efficient Products, FEMP, December 2008.

Documentation Revision History:

Version / Description	Author	Date
1. Put measure together	Franklin Energy Services	7/23/2012
2.0 Add building types and Days variable	Franklin Energy Services	8/6/2012
2.1 Add Flow rate as a variable	Franklin Energy Services	8/6/2012
2.2 Changed the hot water set point from 120°F to 105°F	Franklin Energy Services	8/28/2012
2.3 Added building type to customer/contractor inputs, changed Applicable text	JP	3/25/2013
2.4 Renamed Tset to Tmix, reformulated savings algorithms for consistency with aerators, changed annual hours from 8760 to 8766 and days/yr from 365 to 365.25 for consistency with other measures, changed example accordingly	JP	3/27/2013
2.5 Electric water heater recovery efficiency changed from 0.97 to 0.98 per FES recommendation, updated example accordingly	JP	4/5/2013
2.6 Updated to clarify that spec applies to installation of 1.6 gpm sprayers, removed ability to use flow rate of new sprayer as 1.12 gpm is actual average flow rate in field measured as part of evaluation study in Ref. 1	JP	4/8/2014
2.6 Added federal government purchase requirements and reference.	Franklin Energy Services	8/1/2014

Industrial Compressed Air - No Loss Drains

Version No. 1.1

Measure Overview

Description: This measure includes replacement of a failed or working open tube, timed, or manual condensate drain in a compressed air system with a qualified electronic, pneumatic, or hybrid "no loss drain" that is designed to automatically adjust with system demand and completely eliminate condensate with zero compressed air loss.

Actions: Replace Working, Replace on Fail
Target Market Segments: Industrial
Target End Uses: Industrial Process

Applicable to: Industrial and Commercial Customers

Algorithms

Unit kWh Savings per Year = kW_100_CFM*Hours*Drain_CFM/100

Unit Peak kW Savings = kW_100_CFM*Drain_CFM*CF/100

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 13 (Reference 5)

Unit Participant Incremental Cost =$450/drain (reference 4)

Where:

kW_100_CFM = Compressor efficiency, kW/100 CFM as listed on Compressed Air and Gas Institute (CAGI) datasheet. 20 kW/100 CFM is default value

Hours = Annual hours of operation. 3,528 hr default value. (reference 2)

Drain_CFM = Average CFM of existing drain, 3 CFM (reference 3)

CF = Coincidence Factor = 0.80

Required from Customer/Contractor: CAGI Data Sheet for Air Compressor, Annual Hours of Operation.

Example:

Install a no loss drain on a 40hp compressed air system, with a CAGI efficiency of 16 kW/100CFM and running 2,000 hr/yr

Unit kWh Savings per Year = 16 • 3 • 2000 / 100 = 960

Unit kW Savings per Year = 16 • 3 • 0.8 / 100 = 0.38

Notes:

The default value of 20 kW/100 cfm is from a market survey of 5 yr old model air compressor systems. Kaeser, Sullair, Ingersoll Rand

The average drain loss (cfm) assumes a timed drain system operating approximately 5% of the time. Average size is 1/4" orifice.

Focus on Energy (WI) and New York Standard Approach uses a CF = 0.80.

Consider updating default hours in future update.

References:

1. US Department of Energy. Improving Compressed Air System Performance - A Sourcebook for Industry. November 2003.

2. US Department of Energy. United States Electric Motor Systems Market Opportunities Assessment. Appendix B. Dec 2002.

3. Orr, Ross. The Importance of Condensate Drains on Air System Efficiency. airbestpractices.com. May 2012.

4. Pliske, Jim. Compressed Air System Survey and Consultation. Brabazon Engineered Systems & Technology. Sept 2010.

5. Measure Life Study. Energy & Resource Solutions. Prepared for the Massachusetts Joint Utilities; Table 1-1. 2005.

Documentation Revision History:

Version / Description	Author	Date
1.0 Original Issue	Jim Stebnicki, Franklin Energy Services, LLC	8/28/2012
1.1 Added Replace on Fail to Action Types, changed measure name, added note to consider updating default hours in future update	JP	9/12/2013

Industrial Variable Speed Drive Air Compressors < 50hp

Version No. 1.1

Measure Overview

Description: This measure includes replacement of a inlet modulated, variable displacement, or load/no load controlled air compressor units < 50hp with variable speed drive (VSD) controlled units. Base load units do not qualify.

Actions: Replace Working, Replace on Fail, New Construction
Target Market Segments: Industrial
Target End Uses: Industrial Process

Applicable to: Industrial and commercial customers

Algorithms

Unit kWh Savings per Year = hp * SF * C * hours

Unit Peak kW Savings = hp * SF * C * CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 (reference 1)

Unit Participant Incremental Cost =$428/hp

Where:

Hp =nominal horsepower of VSD air compressor motor

SF =Savings Factor: reference Table 1

Hours =annual facility hours where compressed air is required, default 4024 (reference 2)

C =conversion constant = 0.746 kW/hp

CF =coincidence factor, Default = 0.95

Required from Customer/Contractor: CAGI Data sheet (new), CAGI Data sheet (existing) or nameplate data

Optional inputs from customer/contractor: Annual facility hours where compressed air is required

Example:

Replace an a inlet modulated 25hp air compressor with a 25 hp VSD air compressor

*Unit kWh Savings per Year = 25 * 18% * 0.746 * 4024 = 13,507 kWh*

*Unit kW Savings per Year = 25 * 18% * 0.746 * 0.80 = 3.2 kW*

Deemed Input Tables:

Table 1 - Savings factor for VSD replacing existing control strategy (reference 3)

	Existing Control		
	Inlet Modulating	Load/No Load	Variable Displacement
% Savings Factor	18%	15%	6%

Notes:

$428/hp from surveyed cost from MI and Ohio implemented projects. Full install cost for "replace working"

$100/hp is the incremental cost for replace upon fail or new construction

Focus on Energy (WI) and New York Standard Approach uses a CF = 0.80. The Illinois TRM lists CF = 0.95 and Vectren lists it at 1.0.

Savings factor assumes 75% loaded and the savings factor was interpolated from the part load curves of reference 3 (pages 43-45)

References:

1. Measure Life Study. Energy & Resource Solutions. Prepared for the Massachusetts Joint Utilities; Table 1-1. 2005.

2. US Department of Energy. United States Electric Motor Systems Market Opportunities Assessment. Appendix B. Dec 2002.

3. US Department of Energy. Improving Compressed Air System Performance - A Sourcebook for Industry. Pages 43-45. November 2003.

Documentation Revision History:

Version / Description	Author	Date
1.0 Original Issue	Jim Stebnicki, Franklin Energy Services, LLC	8/28/2012
1.1 Specified that hp corresponds to VSD compressor, added optional input for facility hours, minor fixes	JP-DER	3/4/2013

Public - LED Traffic Signal

Version No. 1.6

Measure Overview

Description: Light Emitting Diode (LED) Traffic Signals are an efficient and effective alternative to traditional incandescent signals. The two main advantages of LED signals are - very low power consumption and very long life. When compared with the typical energy needs of an incandescent bulb, the savings resulting from the low energy usage of LED signals can be as high as 93%.

Actions: Replace working, Replace on Fail, New Construction
Target Market Segments: Public
Target End Uses: Lighting

Applicable to: Exterior traffic signals

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs

Unit Peak kW Savings = (kW_Base - kW_EE) X DF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years): See Table 1

Unit Participant Incremental Cost: See Table 3

Where:

kW_Base = Baseline fixture wattage (kW per fixture) determined from Table 2

kW_EE = High Efficiency fixture wattage (kW per fixture) determined from Table 2

Hrs = Deemed annual operating hours from Table 1 based on lamp type

DF = Deemed diversity factor (see Table 1)

Required from Customer/Contractor: Efficient lamp type/quantity

Example:

Replace (1) incandescent 12" red ball lamp with (1) LED 12" red ball lamp

*kWh Savings = (0.135-0.011)*7,885 = 978 kWh*

*kW Savings = (0.135-0.011)*0.55 = 0.0682 kW*

Deemed Input Tables:

Table 1: Diversity Factor (Ref. 1), Hours (Ref. 1), Measure Life (Ref. 2)

LED Lamp Type	Diversity Factor	Hours	Measure Life
12" Red Arrow	0.90	7,885	6.3
8" Red Arrow	0.90	7,885	6.3
12" Green Ball	0.43	3,675	13.6
8" Green Ball	0.43	3,675	13.6
12" Red Ball	0.55	4,820	10.4
8" Red Ball	0.55	4,820	10.4
12" Yellow Ball	0.02	175	20*
8" Yellow Ball	0.02	175	20*
12" and 8" Yellow Arrow	0.02	701	20*
12" and 8" Green Arrow	0.10	701	20*
Combination walking man/hand large	0.96	4,380	11.4
Walking Man Large	0.21	4,380	11.4
Orange Hand Large	0.75	4,380	11.4
Combination walking man/hand small	0.96	4,380	11.4
Walking Man Small	0.21	4,380	11.4
Orange Hand Small	0.75	4,380	11.4

*Measure life capped for persistence due to an extremely long calculated lifetime based on annual operating hours.

Table 2: Fixture Wattage (Ref.3) and Costs (Ref. 4)

Baseline Device	Efficient Device	kW_base	kW_EE	Incremental Cost
Incandescent, 12" Red Arrow	LED, 12" Red Arrow	0.135	0.009	$60.00
Incandescent, 8" Red Arrow	LED, 8" Red Arrow	0.069	0.007	$115.00
Incandescent, 12" Green Ball	LED, 12" Green Ball	0.135	0.015	$115.00
Incandescent, 8" Green Ball	LED, 8" Green Ball	0.069	0.012	$115.00
Incandescent, 12" Red Ball	LED, 12" Red Ball	0.135	0.011	$60.00
Incandescent, 8" Red Ball	LED, 8" Red Ball	0.069	0.008	$48.00
Incandescent, 12” Yellow Ball	LED, 12” Yellow Ball	0.150	0.013	$60.00
Incandescent, 8” Yellow Ball	LED, 8” Yellow Ball	0.069	0.010	$48.00
Incandescent, 12” and 8” Yellow Arrow	LED, 12” and 8” Yellow Arrow	0.116	0.007	$100.00
Incandescent, 12” and 8” Green Arrow	LED, 12” and 8” Green Arrow	0.116	0.007	$100.00
Incandescent, Pedestrian Large	LED, Combination Walking Man/Hand Large	0.116	0.010	$90.00
Incandescent, Pedestrian Large	LED, Walking Man Large	0.116	0.010	$90.00
Incandescent, Pedestrian Large	LED, Orange Hand Large	0.116	0.010	$90.00
Incandescent, Pedestrian Small	LED, Combination Walking Man/Hand Small	0.069	0.008	$70.00
Incandescent, Pedestrian Small	LED, Walking Man Small	0.069	0.008	$70.00
Incandescent, Pedestrian Small	LED, Orange Hand Small	0.069	0.008	$70.00

References:

1. Technical Reference User Manual Efficiency Vermont 2010, Combination walking man/hand signals used the combined walk & hand signal CFs because it is assumed they will be on the same total time.

2. Measure life in years determined by dividing product lifetime of 50,000 hours by annual operating hours.

3. Consortium of Energy Efficiency

4. NWPCC LEDTrafficSignals_rev-1.xls

Document Revision History:

Version / Description	Author	Date
1) New version replacing LEDTrafficSignalPedestrian_V01,LEDTrafficSignalRedArrow_v01, LEDTrafficSignalRed_v01, LEDTrafficSignalGreen_v01	JP	
1.1) Changed to deemed wattages and incremental costs	JP	3/23/2012
1.2) Updated costs, format	FES	8/31/2012
1.3) Updated CF	FES	11/15/2012
1.4) Minor revisions	JP	2/7/2013
1.5) Added Yellow ball, Yellow Arrow, and Green Arrow signals	FES	2/27/2014
1.6) Minor formatting revisions	JP	5/15/2014

Residential Appliances - ENERGY STAR Clothes Washers

Version No. 2.2

Measure Overview

Description: This measure includes replacement of failed or working clothes washer in existing homes with ENERGY STAR clothes washers.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: Plug Loads

Applicable to: Residential customers in single-family homes and multi-family housing of 2 or more units (including 3- and 4-family homes, duplexes, townhomes and apartment complexes)

Algorithms

Unit kWh Savings per Year = [(Cap x 1/MEF_base x N) x (CW_base + (DHW_base x %Elec_DHW) + (Dry_base x %Elec_dry))] - [(Cap x 1/MEF_prop x N) x (CW_prop + (DHW_prop x %Elec_DHW) + (Dry_prop x %Elec_dry))]

Unit Peak kW Savings = Unit kWh Savings per Year / Hours x CF

Unit Dth Savings per Year = [(Cap x 1/MEF_base x N) x (DHW_base x (1 - %Elec_DHW) x R_eff + Dry_base x (1 - %Elec_dry))] - [(Cap x 1/MEF_prop x N) x (DHW_prop x (1- %Elec_DHW) x R_eff + Dry_prop x (1 - %Elec_dry))] x ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 11 (Ref. 1)

Unit Participant Incremental Cost = $50 (Ref. 2)

Where:

Cap = Clothes washer capacity (ft^3); If unknown, assume 3.5 ft^3 (Ref. 7)

MEF_base = 1.64 (Ref. 7); Modified Energy Factor (ft^3/kWh/cycle)

MEF_prop = See Table 1

N = 299 cycles/yr (Ref. 4)

CW_base = 7% (Ref. 8); Percentage of total energy consumption for clothes washer operation

CW_prop = See Table 1

DHW_base = 33% (Ref. 8); Percentage of total energy consumption for water heating

DHW_prop = See Table 1

%Elec_DHW = See Table 2; Percentage of DHW savings assumed to be electric

Dry_base = 59% (Ref. 8); Percentage of total energy consumption for dryer operation

Dry_prop = See Table 1

%Elec_dry = See Table 2; Percentage of dryer savings assumed to be electric

R_eff = 1.26 (Ref. 11); Recovery efficiency factor

ConversionFactor = 0.003412 Dth/kWh

Hours = 299 hrs; Assumes 1 hour per cycle.

CF = 0.038 (Ref. 12)

Required from Customer/Contractor: washer capacity in ft^3, electric or gas water heating, electric or gas drying, efficiency level (ENERGY STAR, CEE Tier2, CEE Tier 3)

Example:

A residential customer installed a new ENERGY STAR clothes washer (unknown capacity) in a home with an electric water heater and electric dryer.

Unit kWh Savings per Year = [(3.5 ft^3 x 1/1.64 x 299) x (7% + (33% x 100%)) + (59% x 100%)] - [(3.5 ft^3 x 1/2.07 x 299) x (6% + (31% x 100%)) + (62% x 100%)] = 131 kWh

Unit Peak kW Savings = 131 kWh / 299 hours x 0.038 = 0.017 kW

Deemed Input Tables:

Table 1: Clothes Washer Performance Characteristics (Ref. 7, Ref. 8)

Efficiency Level	MEF_prop	CW_prop	DHW_prop	Dry_prop
ENERGY STAR / CEE Tier 1	2.07	6%	31%	62%
CEE Tier 2	2.28	8%	24%	68%
CEE Tier 3	2.71	10%	16%	74%

Table 2: Fuel Types Factors

Fuel Type	%Elec_DHW	%Elec_dry
Electric	100%	100%
Gas	0%	0%
Unknown (Ref. 9 and 10)	39%	81%

Notes:

Table 3: Summarized kWh Savings Values for 3.5 ft³ washers

	Electric Energy Savings			
Efficiency Level	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR / CEE Tier 1	131	77	68	14
CEE Tier 2	173	72	108	8
CEE Tier 3	246	97	155	6

Table 4: Summarized kW Savings Values for 3.5 ft3 washers

	Electric Demand Savings			
Efficiency Level	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR / CEE Tier 1	0.017	0.010	0.009	0.002
CEE Tier 2	0.022	0.009	0.014	0.001
CEE Tier 3	0.031	0.012	0.020	0.001

Table 5: Summarized Dth Savings Values for 3.5 ft3 washers

	Gas Savings (in Dth)			
Efficiency Level	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR / CEE Tier 1	0.00	0.371	0.215	0.586
CEE Tier 2	0.00	0.529	0.220	0.749
CEE Tier 3	0.00	0.694	0.310	1.004

Effective 2007, Federal Standard requires top- and front-loading clothes washers have a MEF ≥ 1.26 and WF ≤ 9.5 (Ref. 5)

Effective March 7, 2015, Federal Standards will require top-loading clothes washers have a MEF ≥ 1.29 and a WF ≤ 8.4 (Ref. 6)

Effective March 7, 2015, Federal Standards will require front-loading clothes washers have a MEF ≥ 1.84 and a WF ≤ 4.7 (Ref. 6)

ENERGY STAR and CEE Tier 1 require top- and front-loading clothes washers have a MEF ≥ 2.0 and WF ≤ 6.0 (Ref. 2)

CEE Tier 2 requires top- and front-loading clothes washers have a MEF ≥ 2.20 and a WF ≤ 4.5 (Ref. 3)

CEE Tier 3 requires top and front-loading clothes washers have a MEF ≥ 2.40 and a WF ≤ 4.0 (Ref. 3)

Effective March 7, 2015, ENERGY STAR Clothes Washers Program Requirements Version 7.0 will require top-loading clothes washers have an IMEF ≥ 2.06 and an IWF ≤ 4.3 (Ref. 13)

Effective March 7, 2015, ENERGY STAR Clothes Washers Program Requirements Version 7.0 will require front-loading clothes washers have an IMEF ≥ 2.38 and an IWF ≤ 3.7 (Ref. 13)

References:

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

2. *Clothes Washers Key Product Criteria,* http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers. Accessed August 15, 2012.

3. CEE High efficiency specifications for residential clothes washers, effective January 1, 2011. http://www.cee1.org/resid/seha/rwsh/reswash_specs.pdf. Accessed August 15, 2012.

4. Weighted average of 299 clothes washer cycles per year (based on 2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, state of MN http://www.eia.gov/consumption/residential/data/2009/xls/HC3.9%20Appliances%20in%20Midwest%20Region.xls

5. 10 CFR Part 430 [Docket No. EE–RM–94–403] RIN 1904–AA67 Energy Conservation Program for Consumer Products: Clothes Washer Energy Conservation Standards. http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/clwshr_rule.pdf.

6. 10 CFR Parts 429 and 430 [Docket Number EERE–2008–BT–STD– 0019] RIN 1904–AB90 Energy Conservation Program: Energy Conservation Standards for Residential Clothes Washers. http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0019-0041

7. MEF values are the average of the from the California Energy Commission (CEC) database of Clothes Washer products; Reference is from the Illinois Technical Reference Manual, June, 2012. Page 304.

8. The percentage of total energy consumption that is used for the machine, heating the hot water or by the dryer is different depending on the efficiency of the unit. Values are based on a sales weighted average of top loading and front loading units based on data from Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/clothes_washers_support_stakeholder_negotiations.html.

9. Percentage of total (gas and electric fuel types) water heating units that are electric calculated from Residential Energy Consumption Survey (RECS) "Table HC8.9. Water Heating in U.S. Homes in Midwest Region, Divisions, and States, 2009". http://www.eia.gov/consumption/residential/data/2009/xls/HC8.9%20Water%20Heating%20in%20Midwest%20Region.xls. Accessed on August 15, 2012.

10. Percentage of total (gas and electric fuel types) dryer units that are electric calculated from Residential Energy Consumption Survey (RECS) "Table HC3.9. Appliances in U.S. Homes in Midwest Region, Divisions, and States, 2009". http://www.eia.gov/consumption/residential/data/2009/xls/HC3.9%20Appliances%20in%20Midwest%20Region.xls. Accessed on August 15, 2012.

11. To account for the different efficiency of electric and Natural Gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency (http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf). Therefore a factor of 0.98/0.78 (1.26) is applied.

12. Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren. Reference is from Illinois Technical Reference Manual June 1, 2012. Page 303.

13. *Clothes Washer Program Requirements Version 7.0*. https://www.energystar.gov/certified-products/sites/products/uploads/files/ENERGY%20STAR%20Final%20Version%207_0%20Clothes%20Washer%20Program%20Requirements.pdf?2c89-939f. Accessed 7/9/14.

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/15/2012
2. Used algorithm from IL TRM	Franklin Energy Services	8/16/2012
2.1 Added text to clarify that Tables 3-5 are for 3.5 ft3 washers	JP	4/2/2013
2.1 Changed End Use from HVAC to Plug Load	JP	4/2/2013
2.2 Added new Energy Star standards to notes	Franklin Energy Services	8/1/2014

Residential Appliances - ENERGY STAR Dishwashers

Version No. 1.1

Measure Overview

Description: This measure includes replacement of failed or working dishwashers in existing homes with ENERGY STAR dishwashers, or installation of ENERGY STAR dishwashers in new homes.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: Plug Loads

Applicable to: Residential customers in single-family homes and multi-family housing of 2 or more units (including 3- and 4-family homes, duplexes, townhomes and apartment complexes)

Algorithms

Unit kWh Savings per Year = (kWh_base - kWh_prop) x (%kWh_op + (%kWh_heat x %Elec_DHW))

Unit Peak kW Savings = Unit kWh Savings per Year / Hours x CF

Unit Dth Savings per Year = (kWh_base - kWh_prop) x %kWh_heat x (1 - %Elec_DHW) x R_eff x ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $50 (Ref. 2)

Where:

kWh_prop = 268 kWh; Energy consumed by efficient dishwasher (Ref. 7)

kWh_base = 355 kWh; Energy consumed by baseline dishwasher (Ref. 7)

%kWh_op = 44%; The percentage of dishwasher energy consumption used for unit operation (Ref. 3)

%kWh_heat = 56%; The percentage of dishwasher energy consumption used for water heating (Ref. 3)

%Elec_DHW = 100% (electric water heating)

= 0% (gas water heating)

= 39% (if unknown) (Ref. 4)

R_eff = 1.26; Recovery efficiency factor

Hours = 269 hours (Ref. 5)

CF = 0.10 (Ref. 6)

ConversionFactor = 0.003412 kWh/Dth

Required from Customer/Contractor: electric or gas water heating

Example:

A residential customer installed a new ENERGY STAR dishwasher in a home with electric water heat.

Unit kWh Savings per Year = (355 kWh - 268 kWh) x (44% + (56% x 100%)) = 87 kWh

Unit Peak kW Savings = 87 kWh / 269 hours x 0.10 = 0.032 kW

Notes (Ref. 7):

Federal Standard requires standard sized dishwashers manufactured before 5/30/2013 use ≤ 355 kWh/yr and ≤ 6.5 gallons of water/cycle

Federal Standard requires standard sized dishwashers manufactured after 5/29/2013 use ≤ 307 kWh/yr and ≤ 5.0 gallons of water/cycle

Federal Standard requires compact sized dishwashers manufactured before 5/30/2013 use ≤ 260 kWh/yr and ≤ 4.5 gallons of water/cycle

Federal Standard requires compact sized dishwashers manufactured after 5/29/2013 use ≤ 222 kWh/yr and ≤ 3.5 gallons of water/cycle

ENERGY STAR requires standard sized dishwashers use ≤ 295 kWh/yr and ≤ 4.25 gallons of water/cycle

ENERGY STAR requires compact sized dishwashers use ≤ 222 kWh/yr and ≤ 3.50 gallons of water/cycle

References:

1. Focus on Energy Evaluation "business Programs: Measure Life Study" Final Report, August 25, 2009. Page 53.

2. State of Illinois Energy Efficiency Technical Reference Manual, June 1, 2012. Page 313.

3. ENERGY STAR Appliance Savings Calculator. http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?e75f-ded1&e75f-ded1. Accessed August 15, 2012.

4. Percentage of total (gas and electric fuel types) water heating units that are electric calculated from Residential Energy Consumption Survey (RECS) "Table HC8.9. Water Heating in U.S. Homes in Midwest Region, Divisions, and States, 2009". http://www.eia.gov/consumption/residential/data/2009/xls/HC8.9%20Water%20Heating%20in%20Midwest%20Region.xls Accessed on August 15, 2012.

5. Assuming one and a half hours per cycle and 179 cycles per year therefore 269 operating hours per year; 179 cycles per year is based on a weighted average of dishwasher usage in MN

http://www.eia.gov/consumption/residential/data/2009/xls/HC3.9%20Appliances%20in%20Midwest%20Region.xls

6. Franklin Energy Services internal standard value

7. *Dishwashers Key Product Criteria,* http://www.energystar.gov/index.cfm?c=dishwash.pr_crit_dishwashers. Accessed August, 15, 2012.

8. To account for the different efficiency of electric and Natural Gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency (http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf). Therefore a factor of 0.98/0.78 (1.26) is applied.

9. Average energy use of qualified standard-sized ENERGY STAR qualified dishwashers

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/15/2012
1.1 Corrected kWh_base and kWh_prop (values were reversed)	JP	4/2/2013
1.1 Changed Target End Use from HVAC to Plug Load	JP	4/2/2013

Residential Appliances - ENERGY STAR Refrigerators and Freezers

Version No. 2.1

Measure Overview

Description: This measure includes the replacement of failed or refrigerators or freezers in residential homes, as well as installation of high efficiency refrigerators and freezers in new homes.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: Plug Loads

Applicable to: Residential customers in single-family homes and multi-family homes, including duplexes and townhomes

Algorithms

Unit kWh Savings per Year = kWh_base - kWh_EE

Unit Peak kW Savings = (Unit kWh Savings per Year) x CF / 8,766

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 14 years for refrigerators, 11 years for freezers (Ref. 1)

Unit Participant Incremental Cost = $40 (Ref. 2)

Where:

kWh_base = Annual energy consumption of the baseline efficiency unit (Refer to Table 1 for refrigerators and Table 2 for freezers)

kWh_EE = Annual energy consumption of the energy efficient unit (Refer to Table 1 for refrigerators and Table 2 for freezers)

8,766 = Assumed annual operating hours per year.

CF = Peak coincidence factor = 1.0 (Ref. 3)

Required from Customer/Contractor: Appliance (refrigerator or freezer), product class (see Tables 1 and 2)

Example:

A conventional side-by-side refrigerator with automatic defrost is replaced with a similar ENERGY STAR side-by-side refrigerator.

Electric Energy Savings (kWh/yr) = 641 - 500 = 141 kWh

*Electric Peak Demand Savings (kW) = 141 kWh / 8,766 * 1.0 = 0.016 peak kW*

Deemed Input Tables:

Table 1: High Efficiency and Conventional Refrigerator Energy Use (kWh). (Ref. 3)

Product Class	ENERGY STAR Rated Model (kWh/year)	Conventional Model (kWh/year)
Refrigerator-freezer or refrigerator only (manual or partial-auto defrost)	380.8	488.3
Top-mounted freezer or refrigerator only (automatic defrost)	423.2	542.5
Side-by-side (automatic defrost)	500.0	641.0
Side-by-side with through-the-door ice (automatic defrost)	530.9	680.7
Bottom-mounted freezer (automatic defrost)	455.6	584.1
Bottom-mounted freezer with through-the-door ice (automatic defrost)	526.5	675.0

Table 2: High Efficiency and Conventional Freezer Energy Use (kWh). (Ref. 3)

Product Class	ENERGY STAR Rated Model (kWh/year)	Conventional Model (kWh/year)
Chest	358.0	407.0
Compact chest	331.0	430.0
Compact upright (manual defrost)	394.0	511.0
Compact upright (auto defrost)	535.0	695.0
Upright (manual defrost)	404.0	459.0
Upright (auto defrost)	578.0	657.0

Notes:

The Federal efficiency standards in place for residential refrigerators and freezers are as follows:

Table 3: Efficiency Standards for Residential Refrigerators and Freezers (Ref. 5)

Product Class	Maximum Energy Use (kWh)
Refrigerator-freezers, partial automatic defrost	8.82AV + 248.4
Refrigerator-freezers, automatic defrost with top-mounted freezer without through-the-door ice service and all refrigerators, automatic defrost	9.80AV + 276.0
Refrigerator-freezers, automatic defrost with side-mounted freezer without through-the-door ice service	4.91AV + 507.5
Refrigerator-freezers, automatic defrost with bottom-mounted freezer without through-the-door ice service	4.60AV + 459.0
Refrigerator freezers, automatic defrost with top-mounted freezer with through-the-door ice service	10.20AV + 356.0
Refrigerator-freezers, automatic defrost with side-mounted freezer with through-the-door ice service	10.10AV + 406.0
Effective for products manufactured on or after July 1, 2001. Standards do not apply to refrigerators and refrigerator-freezers with total refrigerated volume exceeding 39 cubic feet or freezers with total refrigerated volume exceeding 30 cubic feet. AV = total adjusted volume (ft^3)	

References:

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, October 10, 2008

2. Incremental cost from ENERGY STAR Appliance Savings Calculator: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx. Vendor research shows that this value is typical, but that incremental costs vary greatly for this measure.

3. Annual energy use based on default unit volumes, Federal energy standards, and ENERGY STAR requirements as given in the ENERGY STAR calculator referenced above. (Accessed 08/30/12)

4. Title 10, Code of Federal Regulations, Part 430 - Energy Conservation Program for Consumer Products, Subpart C - Energy and Water Conservation Standards and Their Effective Dates. January 1, 2010.

Documentation Revision History:

Version / Description	Author	Date
1. New standalone spec for Refrigerators and Freezers extracted from ResidentialElecAppliancesPlugloads_v02.xlsx (Nexant spec)	JP	
1. Corrected measure life: Nexant had listed 15 years even though the source comments say 14 years	JP	
2. Added to the measure description and algorithms sections.	FES	8/1/2012
2. Changed savings algorithm. Added annual consumption tables.	FES	8/1/2012
2. Added an example.	FES	8/1/2012
2. Changed source for measure life.	FES	8/1/2012
2. Changed incremental costs.	FES	8/1/2012
2. Added federal efficiency standards.	FES	8/1/2012
2.1 Changed Target End Use to Plug Load	JP	4/2/2013
2.2 Changed text of kWh formula for clarify, changed annual hours from 8,760 to 8,766, added coincidence factor of 1 to kW calculation in example, corrected Required Inputs	JP	1/2/2014

Residential Appliances - Secondary Refrigerator/Freezer Removal

Version No. 2.1

Measure Overview

Description: This measure includes the removal and recycling of unneeded secondary residential refrigerators and freezers. Existing units must be working, secondary, refrigerators or freezers. Units must be recycled or otherwise rendered inoperable.

Actions: Remove
Target Market Segments: Residential
Target End Uses: Appliances

Applicable to: Residential customers in single-family homes, duplexes, and townhomes

Algorithms (Ref. 1)

Unit kWh Savings per Year = Gross_Annual_kWh

Unit Peak kW Savings = Gross_kW x PUF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 8 (Ref. 3)

Unit Participant Incremental Cost = $92.20 (Ref. 4)

Where:

Gross_Annual_kWh = the assumed gross savings from removing and recycling a refrigerator or freezer (Refer to Table 1).

PUF = Part-Use Factor, to account for units that may not have been plugged in before being recycled. Assumed to be 0.865 (Ref. 2)

Required from Customer/Contractor: equipment type being recycled (freezer or refrigerator), confirmation of working unit, confirmation of secondary unit

Example:

A secondary refrigerator used limitedly is retired and properly recycled.

Unit kWh Savings per Year = 915

Unit Peak kW Savings = 0.159 x 0.865 = 0.138

Deemed Input Tables:

Table 1: Gross Annual kWh, kW Savings per Unit

Appliance Type	Annual kWh	Gross kW
Refrigerator or Combo Unit	915	0.159
Freezer Only	1,134	0.159

Methodology and Assumptions:

Energy savings are based on a linear regression, using metered data and modeling.

References:

1. Observed average annual kWh consumption for refrigerators and freezers, from the memo: Fridge & Freezer Recycle Rewards Program PY4 Metering Study:
Preliminary Savings Results, May 4, 2012. Prepared for ComEd by Itron and Navigant.

2. PY4 Appliance Recycling Program PJM Post Install M&V Demand Analysis Report Draft, Prepared for Commonwealth Edison Company by Opinion Dynamics Corporation, April 20, 2012.

3. KEMA, “Residential Refrigerator Recycling Ninth Year Retention Study,” July 22, 2004

4. 2008 Database for Energy-Efficient Resources, "Revised DEER Measure Cost Summary," June 2, 2008. This source assumes a $47.00 material cost and a $45.20 installation or labor cost.

Documentation Revision History:

Version / Description	Author	Date
1. New specification based on Nexant version	JP	
2. Added measure description	FES	7/30/2012
2. Changed algorithm and source for algorithm for energy savings and demand savings	FES	7/30/2012
2. Added sources for default values	FES	7/30/2012
2. Added required information from customer/contractor	FES	7/30/2012
2. Changed measure life and EUL source	FES	7/30/2012
2. Changed measure incremental cost and cost source	FES	7/30/2012
2. Added example	FES	7/30/2012
2.1 Added confirmation of working unit, secondary unit to Required Inputs, revised appliance descriptions for clarity	JP	3/29/14

Residential HVAC - Central AC/ASHP

Version No. 2.8

Measure Overview

Description: This measure includes replacement of failed or working central AC system or ASHP in existing homes with high efficiency units, as well as installation of high efficiency AC systems in new homes. Savings for replacement of working units are in reference to existing unit.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family homes, duplexes, townhomes, and multi-family homes (including 3- and 4-family homes) with residential type AC systems

Algorithms

Unit kWh Savings per Year for AC system = Size x EFLCH x (12/SEER_Base - 12/SEER_Eff)

Unit kWh Savings per Year for ASHP = Size x EFLCH x (12/SEER_Base - 12/SEER_Eff) + (Size x HDD_{65} x 24 x Correction Factor x [1/(T_indoor - T_design)] x (12/HSPF_base - 12/HSPF_eff)

Unit Peak kW Savings = CF x Size x (12/EER_Base - 12/EER_Eff)

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 18 years (ref. 1)

Unit Participant Incremental Cost = See Table 2, 3. Incremental equipment cost only, labor is not included

Where:

Size = Unit capacity in tons (1 ton = 12,000 btu/h)

EFLCH = Effective Full Load Cooling Hours. See Table 1.

SEER_Base = SEER of baseline or existing unit provided by customer/contractor, or use SEER = EER / 0.875 if EER is provided. (ref. 4), (SEER_Base = 13 if unknown)

EER_Base = EER of baseline or existing unit provided by customer/contractor, or use EER = SEER x 0.875 if SEER is provided (ref. 4), (EER_Base = 13 X 0.875 = 11.4 if unknown)

SEER_Eff = SEER of new high efficiency unit provided by customer/contractor, or use SEER = EER / 0.875 if EER is provided. (ref. 4)

EER_Eff = EER of new high efficiency unit provided by customer/contractor, or use EER = SEER x 0.875 if SEER is provided (ref. 4)

CF = Coincidence factor = 0.9 (ref. 5)

HSPF_base = Heating system performance factor of baseline or existing ASHP, provided by customer/contractor or use HSPF_base = 7.7 if unknown (ref. 6)

HSPF_eff = Heating system performance factor of efficient ASHP, provided by customer/contractor

Correction Factor = correction factor, assumed to be 0.7 (ref. 7)

HDD_{65} = the heating degree-days of the climate zone, see Table 4

T_indoor = the temperature of the indoor conditioned space, assumed to be 65 F

T_design = the equipment design temperature of the climate zone, see Table 4

Required from Customer/Contractor: Equipment size (tons), SEER or EER of new equipment, SEER or EER of existing equipment (if program includes early replacements), HSPF of new equipment (ASHP only), HSPF of existing equipment (ASHP only, if program includes early replacements), existing equipment condition (working or failed, if program includes early replacements), building type (single family/multifamily*), project location (county)

** Multifamily includes duplexes, townhomes, and multifamily buildings with 3 or more units*

Example:

Retrofit AC System in single family home, 3-ton with SEER rating 14.5, Climate Zone 3.
*Unit kWh Savings per Year = 3 * 520 * (12/13-12/14.5) = 149 kWh*
EER_Eff = 14.5 x 0.875 = 12.7
*Unit Peak kW Savings = 0.9*3*(12/11.4 - 12/12.7) = 0.29 kW*

Retrofit ASHP in single family home, 3-ton with SEER rating 15, HSPF rating 9, Climate Zone 2.
*Unit kWh Savings per Year = 3 * 379 * (12/13-12/15) + (3 * 8512 * 24 * 0.7 * (1/ (65 - (-16.5))) * (12/7.7 - 12/9) = 1325 kWh*
EER_Eff = 15 x 0.875 = 13.125
*Unit Peak kW Savings = 0.9*3*(12/11.4 - 12/13.125) = 0.373 kW*

Deemed Input Tables:

Table 1. Effective Full Load Cooling Hours (EFLCH) by Climate Zone (ref. 3)

Zone	Effective Full Load Cooling Hours	
	Single Family	Multifamily*
Zone 1 (Northern MN)	213	228
Zone 2 (Central MN)	379	473
Zone 3 (Southern MN/Twin Cities)	520	616

**Includes duplex, townhome, and multifamily buildings with 3 or more units*

Table 2. AC Incremental cost (ref. 2)

Efficiency Level	Cost per Ton
SEER 14	$119
SEER 14.5	$178
SEER 15	$238
SEER 16	$357
SEER 17	$476
SEER 18	$596
SEER 19	$715
SEER 20	$834
SEER 21	$908
Average	$530

Table 3. ASHP Incremental cost (ref. 2)

Efficiency Level	Cost per Ton
SEER 14	$137
SEER 15	$274
SEER 16	$411
SEER 17	$548
SEER 18	$685

Table 4: Heating Degrees Days (HDD) and Heating Design Temperature per zone in Minnesota

Minnesota	Zone 1	Zone 2	Zone 3
	(Northern MN)	(Central MN)	(Southern MN/Twin Cities)
HDD_{65} (ref. 8)	9,833	8,512	7,651
T_design (ref. 9)	-22 °F	-16.5 °F	-14.5 °F

Methodology and Assumptions:

EFLH_Cool data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Notes:

The prior national standards for central air conditioners and heat pumps, which raised the minimum Seasonal Energy Efficiency Ratio (SEER) requirement from 10 to 13, became effective in 2006. In January 2010, HVAC manufacturer representatives and efficiency advocates presented a negotiated consensus agreement to DOE to increase efficiency standards for central air conditioners and heat pumps. The consensus agreement included regional standards for three regions: the South, the Southwest, and the North, reflecting varying HVAC needs for each climate. DOE issued a direct final rule (DFR) in June 2011 based on the standard levels in the consensus agreement. These DFR became effective on October 25, 2011. The new standards increase the minimum cooling efficiency requirement to SEER 14 for split system central air conditioners in the South and the SW while maintaining the SEER 13 standard for the North. The new standards also include EER (Energy Efficiency Ratio) requirements for the SW region to ensure efficient operation at high outdoor temperatures. For heat pumps, the standards raise the cooling efficiency requirement to SEER 14 for all three regions and also increase the heating efficiency requirements. The standards will become effective on January 1, 2015. The requirement pertains to the manufacture of units with an 18 month grace period allowed for the sale AC units and a similar period expected for ASHP units.

References:

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007 <http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf>

2. DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com)

3. Calculated through energy modeling be FES 2012

4. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment

5. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.

6. Based on Minimum Federal Standard; http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_cac_hp.html.

7. The correction factor corrects heating usage as building balance points are below 65F, and setback schedules are common. A typical heating degree day correction factor is 0.7. Assuming a typical building balance point temperature of 55F if was found that for a sampling of Minnesota cities HDD55 = 0.7 x HDD65.

8. National Climate Data Center - National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.

9. 2009 ASHRAE Fundamentals Handbook Table 1A Heating and Wind Design Conditions, Heating DB 99.6%

Documentation Revision History:

Version / Description	Author	Date
1 New spec to reflect standalone QI measure in DER Smart Measure Library	JP	
1.1 Added wording to clarify how EER and SEER are calculated	JP	
2.1 Changed energy savings equations arrangement	Franklin Energy	7/25/2012
2.2 Changed measure life	Franklin Energy	7/25/2012
2.3 Changed incremental cost	Franklin Energy	7/25/2012
2.4 Changed references	Franklin Energy	7/25/2012
2.5 Added incremental cost table	Franklin Energy	7/25/2012
2.6 Added to description, added missing customer/contractor inputs	JP	3/25/2013

2.7 Add explanation of multifamily buildings under required customer/contractor inputs, corrected ASHP example calculation, added existing HSPF to Required Inputs (if program includes early replacements of working units.)	JP	3/12/2014
2.8 Federal standard grace period note added	Franklin Energy	07/31/2014

Residential HVAC - Central AC/ASHP Quality Install Additional Savings

Version No. 2.9

Measure Overview

Description:

This measure represents additional savings from installation of high efficiency AC systems or ASHP in existing or new homes through a "Quality Installation" program.

Actions: O&M
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family homes, duplexes, multi-family homes (including 3- and 4-family homes), and townhomes

Algorithms

Unit kWh Savings per Year for AC system = (Size x EFLCH x (12/SEER_Eff) x (1/(1-Loss_No_QI) - 1/(1-Loss_QI)))

Unit kWh Savings per Year for ASHP = (Size x EFLCH x (12/SEER_Eff) x (1/(1-Loss_No_QI) - 1/(1-Loss_QI))) + (Size x HDD_{65} x 24 x Correction Factor x [1/(T_indoor - T_design)] x (12/HSPF_eff) x (1/(1-Loss_No_QI) - 1/(1-Loss_QI))

Unit Peak kW Savings = CF x Size x (12/EER_Eff) x (1 - ((1-Loss_No_QI) / (1-Loss_QI)))

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 18 years (ref. 1)

Unit Participant Incremental Cost = $250/unit (ref. 2)

Where:

Size_cool = Unit capacity in tons (1 ton = 12,000 btu/h)

EFLCH = Effective Full Load Cooling Hours. See Table 1 (ref. 3)

SEER_Eff = SEER of new high efficiency unit provided by customer/contractor, or use SEER = EER / 0.875 if EER is provided. (ref. 4)

EER_Eff = EER of new high efficiency unit provided by customer/contractor, or use EER = SEER*0.875 if SEER is provided (ref. 4)

Loss_No_QI = Efficiency loss of average unit due to improper installation = 25 %. Estimated savings potential with QI ranges from 18% to 36% for air conditioners (ref. 5, 6, 7)

Loss_QI = Efficiency loss of average quality installation = 3.75% in existing homes and 0% in new construction (ref. 8)

CF = Coincidence factor = 0.9 (ref. 9)

Correction Factor = correction factor, assumed to be 0.7 (ref. 7)

HDD_{65} = the heating degree-days of the climate zone, see Table 2

T_indoor = the temperature of the indoor conditioned space, assumed to be 65 F

T_design = the equipment design temperature of the climate zone, see Table 2

HSPF_eff = Heating system performance factor of efficient ASHP, provided by customer/contractor.

Required from Customer/Contractor: Equipment size (tons), SEER or EER of new equipment, HSPF of new equipment (ASHP only), existing or new construction, building type (single family or multifamily*), project location (county)

** Multifamily includes duplexes, townhomes, and buildings with 3 or more units*

Example:

Retrofit AC System installed in single family home, 3-ton with SEER rating 14.5, Climate Zone 3.

*Unit kWh Savings per Year = 3 * 520 * (12/14.5) * (1/ (1-0.25)-1/ (1-0.0375)) = 380*

*Unit Peak kW Savings = 0.9*3*(12/12.7)*(1-((1-0.25)/(1-0.0375)))= 0.56*

Retrofit ASHP in single family home, 3-ton with SEER rating 15, HSPF rating 9, Climate Zone 2.

*Unit kWh Savings per Year = (3 * 379 * (12/15) * (1/ (1-0.25)-1/ (1-0.0375))) + (3 * 8512 * 24 * 0.7 * (1/ (65 - (-16.5))) * (12/9) * (1/ (1-0.25)-1/ (1-0.0375)) = 2334*

*Unit Peak kW Savings = 0.9*3*(12/13)*(1-((1-0.25)/(1-0.0375))) = 0.55*

Deemed Input Tables:

Table 1. Effective Full Load Cooling Hours (EFLCH) by Climate Zone (ref. 3)

Zone	Effective Full Load Cooling Hours	
	Single Family	Multifamily*
Zone 1 (Northern MN)	213	228
Zone 2 (Central MN)	379	473
Zone 3 (Southern MN/Twin Cities)	520	616

** Multifamily includes duplexes, townhomes, and buildings with 3 or more units*

Table 2. Heating Degrees Days (HDD) and Heating Design Temperature per zone in Minnesota

Minnesota	Zone 1	Zone 2	Zone 3
	(Northern MN)	(Central MN)	(Southern MN/ Twin Cities)
HDD_{65} (ref. 10)	9,833	8,512	7,651
T_design (ref. 11)	-22 °F	-16.5 °F	-14.5 °F

Methodology and Assumptions:

Savings with QI consist of four measures: equipment sizing, air flow, refrigerant charge, and duct leakage. The savings for each of four measures are not additive as stated in (6), (7). Our review of the studies' shows the reasonable estimated savings would be 25%, approximately 75% of max savings in studies

To claim Quality Installation savings, a certified technician must sign off on the installation indicating that he or she has inspected the installation and reviewed the submitted data, and verifies that the installation meets proper refrigerant charging and indoor airflow specifications, is sized appropriately according to Manual J calculations, and that ducts have been sealed to the extent practical. In addition, the technician must verify that the indoor and outdoor units are part of a matched system according to the AHRI Certification Directory (www.ahridirectory.org) or other recognized source.

Certification implies that the technician has passed an HVAC certification test by NATE, HVACReducation.net, or a similar organization.

EFLH_Cool data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Notes:

The prior national standards for central air conditioners and heat pumps, which raised the minimum Seasonal Energy Efficiency Ratio (SEER) requirement from 10 to 13, became effective in 2006. In January 2010, HVAC manufacturer representatives and efficiency advocates presented a negotiated consensus agreement to DOE to increase efficiency standards for central air conditioners and heat pumps. The consensus agreement included regional standards for three regions: the South, the Southwest, and the North, reflecting varying HVAC needs for each climate. DOE issued a direct final rule (DFR) in June 2011 based on the standard levels in the consensus agreement. These DFR became effective on October 25, 2011 . The new standards increase the minimum cooling efficiency requirement to SEER 14 for split system central air conditioners in the South and the Southwest while maintaining the SEER 13 standard for the North. The new standards also include EER (Energy Efficiency Ratio) requirements for the Southwest region to ensure efficient operation at high outdoor temperatures. For heat pumps, the standards raise the cooling efficiency requirement to SEER 14 for all three regions and also increase the heating efficiency requirements. The standards will become effective on January 1, 2015. The requirement pertains to the manufacture of units with an 18 month grace period allowed for the sale AC units and a similar period expected for ASHP units.

References:

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007

http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

2. DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com)

3. Calculated through energy modeling be FES 2012

4. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment

5. http://www.energystar.gov/index.cfm?c=hvac_install.hvac_install_index

6. New Jersey Residential HVAC Baseline Study, XENERGY, Inc. November 16, 2001

7. Energy saving Potential From Addressing Residential Air Conditioner And Heat Pump Installation Problems, Chris Neme, Fabruary 1999

8. Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Master's Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

9. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.

10. National Climate Data Center - National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.

11. 2009 ASHRAE Fundamentals Handbook Table 1A Heating and Wind Design Conditions, Heating DB 99.6%

Documentation Revision History:

Version / Description	Author	Date
1 New spec to reflect standalone QI measure in DER Smart Measure Library	JP	
1.1 Added wording to clarify how EER and SEER are calculated	JP	
2.1 Changed energy savings equations arrangement	Franklin Energy	7/25/2012
2.2 Changed measure life	Franklin Energy	7/25/2012
2.3 Changed incremental cost	Franklin Energy	7/25/2012
2.4 Changed references	Franklin Energy	7/25/2012
2.5 Added methodology and assumptions	Franklin Energy	7/25/2012
2.6 Changed description, added missing customer/contractor inputs	JP	3/25/2013
2.7 Changed action to O&M	JP	11/24/2013
2.8 Add explanation of multifamily buildings under required customer/contractor inputs, eliminated existing SEER/EER from existing equipment	JP	3/12/2014
2.9 Federal standard grace period note added	Franklin Energy	07/31/2014

Residential HVAC - Central AC/ASHP Tune-up

Version No. 2.6

Measure Overview

Description: Residential split-system air conditioning tune-up involves inspection of mechanical/electrical components operation, refrigerant charge, airflow, and coils cleaning.

Actions: O&M
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: This measure assumes that the existing unit has not been serviced for at least 2 years for residential customers in single-family homes, duplexes, multi-family homes (including 3- and 4-unit buildings), and townhomes.

Algorithms

Unit kWh Savings per Year = (EFLCH*CAP*(1/SEER))/1000*Mfe

Unit Peak kW Savings = CAP*(1/EER)/1000*MFd*CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 2 (Ref. 4)

Unit Participant Incremental Cost = $175 (default/planning figure; Use actual cost of tune-up) (ref. 4)

Where:

EFLCH = Full Load Cooling Hours, in hr. Depended on location. See table 1 below

CAP = Cooling capacity of AC system or ASHP, in BTU/h. Note 1 ton=12000 BTU/h, default = 2.5-ton (for units with unknown capacity)

SEER = Nameplate efficiency of equipment, default = 10 (for units with unknown efficiency)

EER = Efficiency of equipment (ref. 5), EER = SEER*0.875, default=9.2 ((for units with unknown efficiency)

CF = Coincidence factor = 0.9

MFe = Maintenance energy saving factor, MFe = 5 % (ref. 2)

MFd = Maintenance demand saving factor, MFd = 2 % (ref. 2)

Required from Customer/Contractor: Project location (county), tons, SEER, actual cost of tune-up, building type (single family or multifamily*)

** Multifamily includes duplexes, townhomes, and buildings with 3 or more units*

Example:

Tune up of a 3-ton (36000 BTU/h), 10 SEER AC units in a single family house in Zone 3:

*Unit kWh Savings per Year = (565*36000*(1/10))/1000*0.05 = 102*

Unit Peak kW Savings = 36000(1/9.2)/1000*0.02*0.9 = 0.0704*

Deemed Input Tables:

Table 1. Effective Full Load Cooling Hours (EFLCH) by Climate Zone (ref. 3)

Zone	Effective Full Load Cooling Hours	
	Single Family	Multifamily*
Zone 1 (Northern MN)	213	228
Zone 2 (Central MN)	379	473
Zone 3 (Southern MN/Twin Cities)	520	616

** Multifamily includes duplexes, townhomes, and buildings with 3 or more units*

Methodology and Assumptions:

Measurements and corrections must be performed with standard industry tools and practices, and the results tracked by the efficiency program.

References:

1. Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Master's Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

2. Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

3. Calculated through energy modeling be FES 2012

4. DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com)

5. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment

Documentation Revision History:

Version/Description	Author	Date
1 Initial version based on Nexant's original specification	JP	
1.1 Increased default tune-up cost to $200	JP	
2.1 Changed energy savings equations arrangement	Franklin Energy	7/25/2012
2.2 Changed measure life	Franklin Energy	7/25/2012
2.3 Changed incremental cost	Franklin Energy	7/25/2012
2.4 Changed references	Franklin Energy	7/25/2012
2.5 Changed assumption that unit has not been serviced for at least three years to two years to be consistent with measure life of two years	JP	3/25/2013
2.6 Added explanation of multifamily buildings	JP	3/12/14

Residential HVAC - ECM Blower Motors

Version No. 1.2

Measure Overview

Description:

A new furnace with an ECM blower motor is installed instead of a new furnace with a lower efficiency motor.

This measure characterizes only the electric savings associated with the fan and could be coupled with gas savings associated with a more efficient furnace.

Savings improve when the blower is used for cooling as well and when it is used for continuous ventilation, but only if the non-ECM motor would have been used for continuous ventilation too.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family/multi-family homes, duplexes, and townhomes

Algorithms

Unit kWh Savings per Year = Heating Savings + Cooling Savings + Shoulder Season Savings

Unit Peak kW Savings = Cooling Watts Savings * CF/1000

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil and Propane Savings per Year = 0

Measure Lifetime (years) = 20 (Ref. 1)

Unit Participant Incremental Cost = $250 (Ref. 2)

Where:

Heating Savings = Blower motor savings during heating season = 418 kWh (Ref 3.)

Cooling Savings = Blower motor savings during cooling season. If central AC = 263 kWh. If no central AC = 175 kWh. If unknown = 251 kWh (Ref 4.) If new central AC installed as part of the project, cooling savings equal 0 (Ref. 7).

Shoulder Season Savings = Blower motor savings during shoulder season = 51 kWh (Ref 3.)

Cooling Watts Savings = Cooling Watts Saved = 73 (Ref. 3)

CF = Coincidence factor = 0.9 (Ref. 6)

Required from Customer/Contractor: Central AC present (yes/no/new central AC installed with ECM)

Example:

A blower motor in a home where central AC presence is unknown.

Unit kWh Savings per Year = 418 + 251 + 51 = 720

*Unit Peak kW Savings = 73 * 0.9/1000 = 0.065*

Methodology and Assumptions:

All the assumptions were made based on furnaces analysis in Wisconsin described in study "PA Consulting Group/Patrick Engineering Residential Deemed Savings Review for Focus on Energy, 2009" (ref. 3) and the values were adapted for Minnesota.

References:

1. Consistent with assumed life of a new gas furnace. Table 8.3.3 The Technical support documents for federal residential appliance standards:

http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/chapter_8.pdf

2. Appliance Standards Technical Support Documents

http://www1.eere.energy.gov/buildings/appliance_standards/residential/fb_tsd_0907.html

3. PA Consulting Group/Patrick Engineering Residential Deemed Savings Review for Focus on Energy, 2009

4. The weighted average value is based on assumption that 75% of homes installing BPM furnace blower motors have central AC. (Illinois TRM)

5. Calculated through energy modeling be FES 2012

6. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.

7. Energy use of blower motor during cooling season is reflected in the SEER of the new central AC.

Documentation Revision History:

Version / Description	Author	Date
1. New measure	Franklin Energy	7/31/2012
1.1. Added additional output to Cooling Savings input that cooling savings = 0 if central AC installed as part of project.	JP	4/1/2013
1.2 Removed project location and AFUE from required inputs from customer/contractor, removed Table 1 (EFLH by zone- not needed)	JP	3/2/2014

Residential HVAC - ENERGY STAR Room A/C

Version No. 2.4

Measure Overview

Description: This measure includes the replacement of failed or working room air conditioners in residential homes, as well as installation of high efficiency room air conditioners in new homes.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family homes and multi-family homes (including 3- and 4-unit buildings), including duplexes and townhomes

Algorithms

Unit kWh Savings per Year = ΔkW x Hrs

Unit Peak kW Savings = CF x ΔkW

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 9 years (Ref. 1)

Unit Participant Incremental Cost: See Table 3

Where:

ΔkW = Btuh x (1/EER_base - 1/EER_eff) / 1000

Btuh = Cooling capacity of air-conditioner in Btu/h, provided by customer. If given in tons, 1 cooling ton = 12,000 Btuh.

EER_base = Federal minimum standard energy efficiency ratio (EER) of air-conditioner. Refer to Table 1.

EER_eff = EER of new A/C. Refer to Table 1 for ENERGY STAR standards.

Hrs = Equivalent full load cooling hours. Refer to Table 2.

CF = Peak coincidence factor = 0.9 (Ref. 2)

Required from Customer/Contractor: New unit rated Btuh or tons, new unit EER, new unit type (side louvers or no side louvers), building type (single family/multifamily*), project location (county)

** Multifamily includes duplexes, townhomes, and 3 or more unit buildings*

Example:

A 1-ton (12,000 Btuh), 11.3 EER ENERGY STAR rated window air conditioner is installed in a Climate Zone 1 Single-Family home.

EER_Base = 10.9

ΔkW = 12,000 x (1/10.9 - 1/11.3) / 1000 = 0.039 kW

Electric Energy Savings (kWh/yr) = 0.039 x 228 = 8.89 kWh

Electric Peak Demand Savings (kW) = 0.039 x 0.9 = 0.035 kW

Deemed Input Tables:

Table 1: Baseline and high efficiency EER ratings. (Ref. 3, 6)

<table>
<tr><th></th><th colspan="2">Window Units (w/ louvered sides)</th><th colspan="2">Sleeve Units (w/o louvered sides)</th></tr>
<tr><th>Capacity (Btu/h)</th><th>Federal Minimum Efficiency, EER</th><th>ENERGY STAR Efficiency, EER</th><th>Federal Minimum Efficiency, EER</th><th>ENERGY STAR Efficiency, EER</th></tr>
<tr><td>< 6,000</td><td>11.0</td><td rowspan="2">11.2</td><td rowspan="2">10.0</td><td rowspan="2">10.4</td></tr>
<tr><td>6,000 to 7,999</td><td>11.0</td></tr>
<tr><td>8,000 to 10,999</td><td>10.9</td><td rowspan="2">11.3</td><td>9.6</td><td rowspan="5">9.8</td></tr>
<tr><td>11,000 to 13,999</td><td>10.9</td><td>9.5</td></tr>
<tr><td>14,000 to 19,999</td><td>10.7</td><td>11.2</td><td>9.3</td></tr>
<tr><td>20,000 to 24,999</td><td>9.4</td><td rowspan="2">9.8</td><td rowspan="2">9.4</td></tr>
<tr><td>≥ 25,000</td><td>9.0</td></tr>
</table>

Table 2: Effective full load cooling hours (Ref. 4)

Building Type	Zone 1	Zone 2	Zone 3
Single Family	228	473	616
Multi Family*	213	379	520

** Multifamily includes duplexes, townhomes, and 3 or more unit buildings*

Table 3: Incremental Cost by Capacity (Ref. 5)

Capacity (Btu/h)	Incremental Cost
< 6,000	$19.00
6,000 to 7,999	$27.00
8,000 to 13,999	$43.00
14,000 to 19,999	$66.00
>= 20,000	$85.00

Methodology and Assumptions:

EFLH_Cool data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Notes:

There are currently federal efficiency standards in place for room air conditioners. See Table 1 above for details.

References:

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, October 10, 2008

2. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.

3. ENERGY STAR® Program Requirements, Product Specification for Room Air Conditioners, Version 3.0, June 22, 2010

4. Calculated through energy modeling by FES 2012

5. Costs are averaged from vendor pricing for typical models meeting these criteria.

6. Federal Minimum Efficiency Standards, http://www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0010-0066. Accessed 7/9/14.

Documentation Revision History:

Version / Description	Author	Date
1. Original (derived from ResidentialRoomAC_CentralACTuneup_v02.xls)	JP	
2. Added to the measure description and algorithms sections.	FES	7/30/2012
2. Added an example.	FES	7/31/2012
2. Changed source for measure life.	FES	8/1/2012
2. Changed incremental costs.	FES	8/1/2012
2.1 Added building type to required inputs from customer	JP	4/2/2013
2.2 Added explanation of multifamily buildings	JP	3/12/2014
2.3 Updated to new Federal and ENERGY STAR standards, updated incremental costs	FES	7/31/2014
2.4 Removed mention of existing unit in example, adding EER_Eff to Required Inputs	JP	7/31/2014

Residential HVAC - ENERGY STAR Dehumidifiers

Version No. 2.6

Measure Overview

Description: This measure includes installation of a new ENERGY STAR Dehumidifier or replacement of an old dehumidifier with an ENERGY STAR unit.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers

Algorithms

Unit kWh Savings per Year = (CAP*(Conversion Factor/24)*Hours)*(1/(L/kWhb)-1/(L/kWheff))

Unit Peak kW Savings = Unit kWh Savings per Year/Hours*CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $ 20 (Ref.1)

Where:

CAP = Capacity of the unit in pints/day. CAP = 50 pints/day if unknown

Conversion Factor = 0.473 liters/pints, Constant to convert pints to liters

Hours = 1620 hours/year, Run hours per year (ref. 1)

L/kWhb = Liters of water per kWh removed by baseline unit, as provided in tables below

L/kWheff = Liters of water per kWh removed by new unit, as provided in tables below

CF = 0.37, Coincidence Factor (ref.2)

Required from Customer/Contractor: Unit size

Example:

Install ENERGY STAR humidifier, capacity 50 pints/day,

Unit kWh Savings per Year = (50(0.473/24)*1620)*(1/1.23-1/1.6) = 300*

*Unit Peak kW Savings = 300/1620*0.37 = 0.5*

Deemed Input Tables:

Table 1: Dehumidifiers' baseline efficiency, per Federal Standard efficiency standards

Until 9/30/2012:

Capacity (pints/day)	Federal Standard Criteria (L/kWh)
≤25	≥1.10
> 25 to ≤35	≥1.20
> 35 to ≤45	≥1.20
> 45 to ≤ 54	≥1.23
> 54 to ≤ 75	≥1.55
> 75 to ≤ 185	≥1.90

After 10/1/2012:

Capacity (pints/day)	Federal Standard Criteria (L/kWh)
≤35	≥1.35
> 35 to ≤45	≥1.50
> 45 to ≤ 54	≥1.60
> 54 to ≤ 75	≥1.70
> 75	≥2.5

Table 2: Dehumidifiers' ENERGY STAR standards

Until 9/30/2012 (V 2.1):

Capacity (pints/day)	ENERGY STAR Criteria (L/kWh)
≤25	≥1.20
> 25 to ≤35	≥1.40
> 35 to ≤45	≥1.50
> 45 to ≤ 54	≥1.60
> 54 to ≤ 75	≥1.80
> 75 to ≤ 185	≥2.50

After 10/1/2012 (V 3.0)

Capacity (pints/day)	ENERGY STAR Criteria (L/kWh)
<75	≥1.85
75 to ≤185	≥2.80

Methodology and Assumptions:

A dehumidifier meeting the minimum qualifying efficiency standard established by the current ENERGY STAR (Version 2.1 or 3.0) is purchased and installed in a residential setting in place of a unit that meets the minimum federal standard efficiency.

Notes:

To qualify for this measure, the new dehumidifier must meet the ENERGY STAR standards.

Qualifying units shall be equipped with an adjustable humidistat control or shall require a remote humidistat control to operate.

References:

1. ENERGY STAR website

http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=DE

2. Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). 1620 operating hours from ENERGY STAR calculator for dehumidifiers[1]. Coincidence peak during summer peak is therefore 1620/4392 = 36.9%

Documentation Revision History:

Version / Description	Author	Date
1 New standalone spec sheet, based on March 2009 evaluation report for Focus on Energy as noted in references	JP	
2.1 Changed energy savings equations arrangement	Franklin Energy	7/25/2012
2.2 Added Example	Franklin Energy	7/25/2012
2.3 Added input tables	Franklin Energy	7/25/2012
2.4 Added Notes	Franklin Energy	7/25/2012
2.5 Added Methodology and Assumption	Franklin Energy	7/25/2012
2.6 Spelling fixes, minor wording changes	JP	3/26/2013

Residential HVAC - Programmable Thermostats with Electric Heating

Version No. 1.3

Measure Overview

Description: This measure includes replacement of failed or working manual thermostats in existing homes with programmable thermostats. New units must have the capability to adjust temperature setpoints according to a schedule without manual intervention. An estimate is provided for reduced heating energy consumption through temperature set-back during unoccupied or reduced demand times. Savings are provided for heating only as a literature review has not shown conclusive cooling savings.

Actions: Replace on Fail, Replace Working
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family homes, duplexes, townhomes, and multi-family homes (including 3- and 4-family homes) with residential type heating equipment. Electricity must be the primary heating source to use this measure.

Algorithms

Unit kWh Savings per Year = HHCelec x HSF x HF x ISR

Unit Peak kW Savings = 0

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 1)

Unit Participant Incremental Cost: $30 (Ref. 2)

Where:

HHCelec = Household heating consumption for electrically heated single family homes, see Table 1. (Ref. 3)

HSF = Heating Savings Factor, assumed fraction reduction in heating energy consumption due to programmable thermostat, HSF = 0.062 (Ref. 4)

HF = Household factor, to adjust consumption for non-single family households, see Table 2. (Ref. 5)

ISR = In-Service Rate, the percentage of units installed and programmed effectively, Table 3. (Ref. 6)

Required from Customer/Contractor: Confirmation of electric heating, household type (see Table 2), program delivery type (see Table 3), location (county)

Examples:

Retrofit a manual thermostat with a programmable thermostat in an electrically heated multifamily apartment Climate Zone 1, via a direct installation program delivery.

*Unit kWh Savings per Year = 10,000 * 0.062 *0.65 * 1.0 = 403 kWh*

Deemed Input Tables:

Table 1: Household heating consumption in residential homes per zone in Minnesota (Ref. 3)

Minnesota	Zone 1	Zone 2	Zone 3
Household Heating Consumption	(Northern MN)	(Central MN)	(Southern MN/Twin Cities)
HHCelec, Electric Heating, kWh	10,000	8,300	7,400

Table 2: Household Factor (Ref. 5)

Household Type	HF
Single-Family	1.0
Duplexes, Townhomes, and Multifamily*	0.65

** Includes buildings with 3-more units*

Table 3: In-Service Rates (Ref. 6)

Program Delivery	ISR
Direct Install	1.0
Other, or unknown	0.56

Methodology and Assumptions:

Primary assumption is having an existing manual thermostat replaced by a programmable thermostat, with a setback of at least 5 degrees each night. Households are assumed to be heated primarily by electricity. Households with a combination of heating fuels may be addressed on a custom basis by proportioning the amount of electric and gas heat. As savings is dependent on household consumption, households with multiple thermostats shall not attain savings beyond that of the installation of one thermostat.

Notes:

Energy Star is developing a new specification for this measure category, if/when evaluation results demonstrate consistent cooling savings, subsequent versions of this measure will revisit potential cooling savings.

Upon adoption of International Energy Conservation Code (IECC) 2012 any new forced-air furnace system will require programmable thermostat control. This will become the baseline for new furnace installations.

References:

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007

http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

2. Market price vary significantly for this product, the basic functions required are available on units readily available in the market for the listed price. (Illinois Statewide Technical Reference Manual for Energy Efficiency Version 3.0, 2014)

3. Consumption values are based on 2012 Minnesota household electric and natural gas consumption in the three climate zones corrected for baseline usage and normalized for the typical heating season.

4. "Validating the Impacts of Programmable Thermostats, Final Report", RWL Analytics, 2007

5. Multifamily household heating consumption relative to single family households is affected by overall square footage and exposure to the exterior. The 0.65 factor is applied to multifamily homes based on professional judgment that this represents average household size and heat loads. (Illinois Statewide Technical Reference Manual for Energy Efficiency Version 3.0, 2014)

6. "Programmable Thermostats. Report to KeySpan Energy Delivery on Energy and Cost Effectiveness," GDS Associates, Marietta, GA. 2002

Document Revision History:

Version / Description	Author	Date
1.0 Measure Created	Franklin Energy	2/28/2014
1.1 Added duplexes to multifamily category	JP	3/11/2014
1.2 Added IECC 2012 note	Franklin Energy	7/31/2014
1.3 In Methodology and Assumption, changed "solely" to"primarily" regarding electric heating for consistency with Description.	JP	7/31/2014

Residential Lighting - CFLs and ENERGY STAR Torchieres

Version No. 2.5

Measure Overview

Description: CFLs and ENERGY STAR qualified torchieres provide an energy efficient alternative to traditional incandescent and halogen lamps.

Actions: Replace on Failure, Replace Working, New Construction
Target Market Segments: Residential, Commercial
Target End Uses: Lighting

Applicable to: Single family, duplex, townhome, and multifamily (3+ units) customers

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = (kW_Base - kW_EE) x CF x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = CFL 9.4 years (Ref 1), ENERGY STAR Torchiere 9.4 years (Ref 2)

Unit Participant Incremental Cost: See Table 3

Where:

kW_EE = Deemed average wattage efficient luminaire per Table 3

kW_Base = Deemed average wattage of baseline luminaire per Table 3

Hrs = Deemed annual operating hours from Table 2 based on building type.

PAF = Deemed Power Adjustment Factor per Table 3.

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in Table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting (Ref. 3).

Required from Customer/Contractor: device type (CFL lamp or ENERGY STAR Torchiere), space type (interior living quarters, multifamily* common areas, or exterior/unconditioned space), HVAC System (heating only, heating & cooling, exterior/unconditioned)

** Multifamily includes 3+ unit residential buildings*

Example:

Install a CFL to replace an incandescent lamp in a single family home with Central A/C.

*kWh = (0.0488-0.019) * 938 *1.075 = 30.0 kWh*

*kW = 0.095 *(0.0488-0.019) * 1.248 = 0.004 kW*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)	
Space Type	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only or Heating & Cooling**	**Reference**
Interior Living Quarters	1.00	1.248	1.00	1.075	-0.0029	3
Multifamily Common Areas	1.00	1.248	1.00	1.075	-0.0029	3
Exterior/Unconditioned Space	1.00	1.00	1.00	1.00	0	3
Interior Living Quarters - Cooling Unknown	1.00	1.16	1.00	1.048	-0.0019	10
Multifamily Common Areas - Cooling Unknown	1.00	1.11	1.00	1.034	-0.0013	11

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 4 and 8) and Annual Operating Hours by Space Type (see table for references)

Space Type	CF	Hrs	Reference
Interior living quarters	9.5%	938	5
Multifamily Common Areas	75%	5,950	6
Exterior/Unconditioned Space	0%	1,825	5

Table 3: Fixture Wattage (Ref. 7 and 10) and Costs (Ref. 9 and 12)

Equipment Type	kW_base	kW_EE	Incremental Cost
CFL	0.0488	0.0190	$1.32
ENERGY STAR Torchiere	0.1900	0.0491	$41.97

Methodology and Assumptions:

The baseline wattages in Table 3 were derived from extrapolating the approved baseline wattages for Xcel Energy's Home Lighting program for 2012- 2014 in a February 14, 2012 Order (Docket No. E,G002/CIP-09-198), shown below, and using the market share of each wattage range shown in Table 5. The wattages reflect the gradual depletion of traditional incandescent lighting from the market and were derived from the following report:

United States Environmental Protection Agency, October 2011. *Next Generation Lighting Programs: Opportunities to Advance Efficient Lighting for a Cleaner Environment.*

Table 4: Approved Baseline Wattages for Xcel Energy's Home Lighting Program, 2012-2014, with Extrapolation to 2015 and 2016

Lumen Bin	Typical Incandescent Wattage	EISA-Compliant Halogen Wattage	2012	2013	2014	2015	2016+
1490-2600	100W	72W	90.5 W	80.5 W	76.0 W	72.0W	72.0W
1050-1489	75W	53W	72.0 W	64.0 W	57.5 W	53.0W	53.0W
750-1049	60W	43W	58.5 W	55.0 W	48.5 W	46.1W	43.0W
310-749	40W	29W	39.0 W	37.0 W	33.0 W	31.4W	29.0W

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Tables 5-6: Composite wattages and costs for CFLs and baseline incandescents. Source: CFL METERING STUDY FINAL REPORT, Prepared for: Pacific Gas & Electric Company, San Diego Gas & Electric Company, Southern California Edison Company, 2005. Incandescent wattages updated for EISA 2007 new wattages and include market lag effect for gradual depletion of traditional incandescent wattages from the market per February 14, 2012 Order for Xcel Energy (Docket No. E,G002/CIP-09-198).

CFL Wattage Range Avg	Percent of Total Res CFLs	Composite CFL Wattage	Comparable Incandescent and Halogen Wattage 2015	Composite Baseline Wattage 2015
11	12.0%	1.32	31.4	3.8
17	57.0%	9.69	46.1	26.3
25	19.0%	4.75	53.0	10.1
27	12.0%	3.24	72.0	8.6
	Weighted Average	**19.0**		**48.8**

CFL Wattage Range Avg	CFL Cost	Incandescent cost	Composite CFL Cost	Composite Incandescent Cost	Incremental
11	$2.23	$0.50	$0.27	$0.06	$0.21
17	$2.00	$0.75	$1.14	$0.43	$0.71
25	$1.87	$0.85	$0.36	$0.16	$0.19
27	$2.25	$0.50	$0.27	$0.06	$0.21
			$2.03	**$0.71**	**$1.32**

Table 7: Composite Wattages calculated from ENERGY STAR Qualified Product list accessed 8/29/2012

Brand	Model Number	Intended for Commerical use, Residential, or Both?	Lighting Technology Used	Fixture Type	Light Output	Total Input Power (Watts)
AutoCellÂ Electronics	57W-TOR-27KYN	Residential	Fluorescent	Torchieres	3900	57
AutoCellÂ Electronics	57W-TOR-41KYN	Residential	Fluorescent	Torchieres	3900	57
Hampton Bay	HBP1042P-x	Residential	Fluorescent	Torchieres	3200	48
Exceedlite	ELF4004x	Residential	Fluorescent	Torchieres	3101.31	42.42
Greenlite	59W/3WAY/T/BK	Residential	Fluorescent	Torchieres	4161	56.98
Greenlite	59W/3WAY/T/WH	Residential	Fluorescent	Torchieres	4161	56.98
Verlux Lighting	VL-ET-41-01 X	Residential	Fluorescent	Torchiere	1550.956	35.53
MaxLite	ML1G4523xxxx	Residential	Fluorescent	Torchieres	3230	44
MaxLite	ML1G7033xxxx	Residential	Fluorescent	Torchieres	3230	44
					Average	**49.10**

Notes:

Baseline incandescent lamp wattages are decreased through 2014 based on EISA 2007 legislation.
Torchieres. Section 135(c) of EPACT 2005 amends section 325 of EPCA to add subsection (x) setting standards for torchieres. Torchieres manufactured on or after January 1, 2006, shall consume not more than 190 watts of power, and shall not be capable of operating with lamps that total more than 190 watts.

References:

1. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08 (range from 2-10, 9.4 years was selected)

2. Measure life: 9.4 years (calculated), based on 10,000 hour average lamp life

3. Calculated through energy modeling be FES 2012

4. Based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation. “ComEd Residential Energy Star Lighting Program Metering Study: Overview of Study Protocols” http://www.icc.illinois.gov/downloads/public/edocket/303835.pdf
“Memo RE: Lighting Logger Study Results – Version 2, Date: May 27, 2011, To: David Nichols and ComEd Residential Lighting Interested Parties, From: Amy Buege and Jeremy Eddy; Navigant Evaluation Team” http://www.icc.illinois.gov/downloads/public/edocket/303834.pdf

5. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 7.5 based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation.

6. Multifamily common area lighting assumption is 16.3 hours per day (5950 hours per year) based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010.

7. Torchiere ENERGY STAR Light Fixtures Product List - accessed 8/29/2012 and summarized in the Assumptions tab.

8. Coincidence factor is based on healthcare/clinic value (used as proxy for multifamily common area lighting with similar hours of use) developed using Equest models for various building types averaged across 5 climate zones for Illinois for the following building types.

9. 2006 MEEA Change A Light Change the World Program for 15W and 26W lamps.

10. As above but using estimate of 64% of single family and multifamily in unit buildings in Minnesota having central cooling (based on data from "Table HC7.1 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009"

11. As above but using estimate of 45% of multifamily buildings in Minnesota having central cooling (based on data from "Table HC7. Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to MN air conditioning prevalence compared to US average);

12. Refer to Assumptions tab for more detailed information on the weighting of costs. Costs are based on a survey of manufacturers and Midwest program data.

Document Revision History:

Version / Description	Author	Date
1) New spec combining ResidentialCFLs_v01, ResidentialTorchieres_v01, LEDHoliday_V01	JP	
2) Updated format, CFs, Ifs, Hours, Sources, and measure life.	FES	8/31/2012
2.1) Minor changes to header information		
2.1) Changed "building type" to "space type", changed Residential to Single Family where appropriate	JP	4/3/2013
2.2) Incorporated market lag baseline wattages from 2.14.12 Xcel Energy Order, updated example for 2014 figures, added device type (CFL or Torchiere) as required input from customer/contractor	JP	2/4/2014
2.3) Modified description building type descriptions to clarify multifamily	JP	3/12/2014
2.4) Adjusted baseline wattages for EISA compliance	FES	7/31/2014
2.5 Updated Example and Table 3 to use new baseline wattages	JP	7/31/2014

Residential Lighting - ENERGY STAR Ceiling Fan

Version No. 2.1

Measure Overview

Description:

ENERGY STAR qualified ceiling fan/light combination units are over 50% more efficient than conventional fan/light units. They also use improved motors and blade designs.

Includes fan-only and fan + light options

Actions: Replace on Failure, Replace Working, New Construction
Target Market Segments: Residential, Multi-Family
Target End Uses: Lighting

Applicable to: Residential and multifamily customers

Algorithms

Unit kWh Savings per Year = ((Fan $_{kW\ base}$ + Fixture $_{kW\ base}$) - (Fan $_{kW\ EE}$ + Fixture $_{kW\ EE}$)) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings per Year = Electric Peak Demand Savings (kW) = CF x ((Fan $_{kW\ base}$ + Fixture $_{kW\ base}$) - (Fan $_{kW\ EE}$ + Fixture $_{kW\ EE}$)) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = Natural Gas Savings (Dth/yr) =((Fan $_{kW\ base}$ + Fixture $_{kW\ base}$) - (Fan $_{kW\ EE}$ + Fixture $_{kW\ EE}$)) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 years (Ref. 1)

Unit Participant Incremental Cost: See Table 3

Where:

Fan $_{kW\ base}$ = Baseline fan wattage (kW per fan) determined from Table 3

Fixture $_{kW\ base}$ = Baseline fixture wattage (kW per fixture) determined from Table 3

Fan $_{kW\ EE}$ = High Efficiency fan wattage (kW per fan) determined from Table 3

Fixture $_{kW\ EE}$ = High Efficiency fixture wattage (kW per fixture) determined from Table 3

Hrs = Deemed annual operating hours from Table 2 based on building type.

PAF = Deemed Power Adjustment Factor per Table 3.

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting (Ref. 2).

Required from Customer/Contractor: Space type (Single Family/Multi Family in Unit, Multi Family Common Area, Exterior/Unconditioned Space), HVAC System (Heating Only or Heating & Cooling)

Example:

Install an ENERGY STAR qualified ceiling fan with light kit in a single family home

*kWh = ((0.0345+0.180)-(0.0315+0.060)) * 938 *1.075 = 124.03 kWh*

*kW = 0.095 *((0.0345+0.180)-(0.0315+0.060)) * 1.248 = 0.015 kW*

*Dth/year = ((0.0345+0.180)-(0.0315+0.060)) * 938 * -0.0029 = -0.335 Dth/year*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)	
Space Type	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only**	**HVAC System: Heating & Cooling**	**HVAC System: Heating Only or Heating & Cooling**	**Reference**
Single Family and Multi Family in Unit	1.00	1.248	1.00	1.075	-0.0029	2
Multi Family Common Areas	1.00	1.248	1.00	1.075	-0.0029	2
Exterior/Unconditioned Space	1.00	1.00	1.00	1.00	0	2
Single Family and Multi Family In Unit - Cooling Unknown	1.00	1.16	1.00	1.048	-0.0019	8
Multi Family Common Areas - Cooling Unknown	1.00	1.11	1.00	1.034	-0.0013	9

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 3 and 7) and Annual Operating Hours by Building Type (see table for references)

Space Type	CF	Hrs	Reference
Single Family and Multi Family in Unit	9.5%	938	5
Multi Family Common Areas	75%	5,950	6
Exterior/Unconditioned Space	0%	1,825	5

Table 3: Fixture Wattage and Costs (Ref. 4)

Retrofit Category	Existing Device	Replacement Device	kW_base	kW_EE	Incremental Cost
ENERGY STAR Ceiling Fan (Fan wattage)	Conventional Unit Fan Wattage	ENERGY STAR qualified unit Fan Wattage	0.0345	0.0315	$86.00
ENERGY STAR Ceiling Fan (Fixture wattage)	Conventional Unit Fixture Wattage	ENERGY STAR qualified unit Fixture Wattage	0.1800	0.0600	$86.00

Methodology and Assumptions:

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Notes:

Effective January 1, 2007 (EPAct): Shall have the following features: fan speed controls separate from any lighting controls; adjustable speed controls; the capability of reversible fan action. Specific to ceiling fan light kits, (A) Light kits with medium screw based sockets shall be packaged with screw based lamps to fill each socket that: (i) meet the ENERGY STAR CFL V3.0; (ii) use light sources other than CFL that have lumens per watt performance at least equivalent to the ENERGY STAR CFL V3.0 requirements. (B) Light kits with pin-based sockets for fluorescent lamps shall meet the ENERGY STAR RLF V4.0 and be packaged with lamps to fill all sockets. Packaging must include FTC energy information label.

Effective January 1, 2009: All other lamp types, maximum total wattage of 190 watts.

References:

1. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08 (range from 13-16 years, 15 years was selected)

2. Calculated through energy modeling be FES 2012

3. Based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation. "ComEd Residential Energy Star Lighting Program Metering Study: Overview of Study Protocols" http://www.icc.illinois.gov/downloads/public/edocket/303835.pdf
"Memo RE: Lighting Logger Study Results – Version 2, Date: May 27, 2011, To: David Nichols and ComEd Residential Lighting Interested Parties, From: Amy Buege and Jeremy Eddy; Navigant Evaluation Team" http://www.icc.illinois.gov/downloads/public/edocket/303834.pdf

4. ENERGY STAR Ceiling Fan calculator (Ceiling_Fan_Savings_Calculator_Consumer.xls) accessed 8/29/2012

5. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 7.5 based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation.

6. Multifamily common area lighting assumption is 16.3 hours per day (5950 hours per year) based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010.

7. Coincidence factor is based on healthcare/clinic value (used as proxy for multifamily common area lighting with similar hours of use) developed using Equest models for various building types averaged across 5 climate zones for Illinois for the following building types.

8. As above but using estimate of 64% of single family and multifamily in unit buildings in Minnesota having central cooling (based on data from "Table HC7.1 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009"

9. As above but using estimate of 45% of multifamily buildings in Minnesota having central cooling (based on data from "Table HC7. Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to MN air conditioning prevalence compared to US average);

Document Revision History:

Version / Description	Author	Date
1)New standalone spec sheet, extracted from ResidentialElecAppliancesPlugloads_v02 created by Nexant	JP	
2) Updated format, CFs, lfs, Hours, Sources, measure life, added specification notes	FES	8/31/2012
2.1) Corrected gas savings algorithm (added Hrs), modified description to specify that measure can be used with fan-only or fan + light options, corrected Inputs from customer/contractor	JP	4/1/2013

Residential Lighting – ENERGY STAR LED Lamps and Fixtures

Version No . 1.3

Measure Overview

Description: ENERGY STAR LED lamps and fixtures provide an energy efficient alternative to traditional incandescent and halogen lamps. The ENERGY STAR program began labeling qualified LED products in the latter half of 2010. LED A-line lamps are used as efficient replacements of general service incandescent lamps and more efficient halogen lamps. LED Globes are commonly used in restroom vanity fixtures and offer an efficient alternative to incandescent lamps. LED PAR/Flood lamps are commonly used in downlights and track lighting and replace less efficient incandescent and halogen lamps. Recessed downlight fixtures are common in living rooms, bedrooms, and rec rooms and are typically incandescent lamps. LED recessed downlight fixtures offer an efficient alternative to the incandescent fixtures.

Actions: Replace on Failure, Replace Working, New Construction
Target Market Segments: Residential, Commercial
Target End Uses: Lighting
Applicable to: Single family, duplex, townhome, and multifamily (3+ unit) customers

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = (kW_Base - kW_EE) x CF x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = LED screw in lamps 10 years (Ref 1), LED downlights 15 years (Ref 2)

Unit Participant Incremental Cost: See Table 3

Where:

kW_EE = Deemed average wattage efficient luminaire per Table 3

kW_Base = Deemed average wattage of baseline luminaire per Table 3

Hrs = Deemed annual operating hours from Table 2 based on building type.

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: LED lamp or fixture type (see Table 3), space type (interior living quarters, multifamily* common areas, exterior/unconditioned), HVAC system (heating only, heating & cooling, or exterior/unconditioned)

** Multifamily includes 3+ unit buildings*

Example:

Install a 13W A-line LED lamp in a single family home with central A/C.

*kWh = (0.049-0.013) * 938 *1.075 = 36.3 kWh*

*kW = 0.095 *(0.049-0.013) * 1.248 = 0.004 kW*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)	
Space Type	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only or Heating & Cooling	Reference
Interior Living Quarters	1.00	1.248	1.00	1.075	-0.0029	3
Multifamily Common Areas	1.00	1.248	1.00	1.075	-0.0029	3
Exterior/Unconditioned Space	1.00	1.00	1.00	1.00	0	3
Interior Living Quarters - Cooling Unknown	1.00	1.16	1.00	1.048	-0.0019	10
Multi Family Common Areas - Cooling Unknown	1.00	1.11	1.00	1.034	-0.0013	11

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 4 and 8) and Annual Operating Hours by Space Type (see table for references)

Space Type	CF	Hrs	Reference
Interior Living Quarters	9.5%	938	5
Multifamily Common Areas	75%	5,950	6
Exterior/Unconditioned Space	0%	1,825	5

Table 3: Fixture Wattage (Ref. 7) and Costs (Ref. 9)

LED Lamp or Fixture	kW_base	kW_EE	Incremental Cost
20W LED A-Line Lamp	0.076	0.020	$15.00
16W LED A-Line Lamp	0.058	0.016	$13.00
13W LED A-Line Lamp	0.049	0.013	$10.00
9W LED A-Line Lamp	0.033	0.009	$8.00
3W LED Globe Lamp	0.025	0.003	$11.00
8W LED Globe Lamp	0.050	0.008	$13.00
14W LED PAR/Flood Lamp	0.078	0.014	$15.00
12W LED Downlight Fixture	0.065	0.012	$85.00

Methodology and Assumptions:

For 2012 100W incandescent lamps were changed to 72W halogen EISA compliant lamps making the baseline wattage 72W.

For 2013 in additional to 100W incandescent lamps already being changed, 75W lamps were changed to 53W halogen EISA compliant lamps.

For 2014 in addition to 100W and 75W incandescent lamps already being changed, 60W and 40W lamps will be changed to 43W and 29W halogen EISA compliant lamps respectively.

The baseline wattages in Table 3 reflect the approved baseline wattages for Xcel Energy's Home Lighting program in a February 14, 2012 Order (Docket No. E,G002/CIP-09-198), shown below. The wattages reflect the gradual depletion of traditional incandescent lighting from the market and were derived from the following report:

United States Environmental Protection Agency, October 2011. *Next Generation Lighting Programs: Opportunities to Advance Efficient Lighting for a Cleaner Environment.*

Table 4: Approved Baseline Wattages, Xcel Energy's Home Lighting Program

Lumen Bin	Typical Incandescent Wattage	EISA-Compliant Halogen Wattage	2012	2013	2014
1490-2600	100W	72W	90.5 W	80.5 W	76.0 W
1050-1489	75W	53W	72.0 W	64.0 W	57.5 W
750-1049	60W	43W	58.5 W	55.0 W	48.5 W
310-749	40W	29W	39.0 W	37.0 W	33.0 W

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Codes and Standards:

The following tables indicate the effective phase out dates of incandescent lamps under the Energy Independence and Security Act of 2007 (EISA 2007) and technical information.

Wattage and Lumen Ranges for General Service Incandescent Types				
Incandescent Lamp Wattage	Rated Lumen Range	Replacement Maximum Rated Wattage	Minimum Rated Lamp Life	Effective Phase-Out Date Products Manufactured on or after:
100	1490-2600	72	1,000 hrs	1/1/2012
75	1050-1489	53	1,000 hrs	1/1/2013
60	750-1049	43	1,000 hrs	1/1/2014
40	310-749	29	1,000 hrs	1/1/2014

Incandescent reflector lamps (IRLs) are common cone-shaped light bulbs most typically used in track lighting and “recessed can” light fixtures. The table below shows lumen ranges and incandescent equivalents for LED reflector lamps based on EISA 2007 amendment for reflector lamps in residential settings.

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Wattage
2340	3075	150
1682	2339	120
1204	1681	100
838	1203	75
561	837	60
420	560	45

Requirements and Qualifications:

All LED lamps and fixtures must be ENERGY STAR qualified. Criteria for ENERGY STAR qualified LED products vary by product type and include specifications for: light output (lumens), efficacy (lumens per Watt), zonal lumen density, Correlated Color Temperature (CCT), lumen maintenance (lifetime), Color Rendering Index (CRI), and power factor, among others. LED bulbs also have three-year (or longer) warranties covering material repair or replacement from the date of purchase and must turn on instantly.

References:

1. NEEP EMV Emerging Technologies Research Report (December 2011) – measure life capped at 10 years due to persistence.

2. Focus on Energy Evaluation "Business Programs: Measure Life Study" August 25, 2009

3. Calculated through energy modeling be FES 2012

4. Based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation. "ComEd Residential Energy Star Lighting Program Metering Study: Overview of Study Protocols" http://www.icc.illinois.gov/downloads/public/edocket/303835.pdf "Memo RE: Lighting Logger Study Results – Version 2, Date: May 27, 2011, To: David Nichols and ComEd Residential Lighting Interested Parties, From: Amy Buege and Jeremy Eddy; Navigant Evaluation Team" http://www.icc.illinois.gov/downloads/public/edocket/303834.pdf

5. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 7.5 based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation.

6. Multifamily common area lighting assumption is 16.3 hours per day (5950 hours per year) based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010.

7. Baseline wattages are from EISA 2007 phase out table for general service incandescents. Baseline wattages for PAR/Floods were averaged based on available products. Baseline for downlights is based on the average downlight fixture. ENERGY STAR efficient wattages are from product information and available qualified products.

8. Coincidence factor is based on healthcare/clinic value (used as proxy for multifamily common area lighting with similar hours of use) developed using Equest models for various building types averaged across 5 climate zones for Illinois for the following building types.

9. Costs are based on manufacturer product surveys and Midwest program data.

10. As above but using estimate of 64% of single family and multifamily in unit buildings in Minnesota having central cooling (based on data from "Table HC7.1 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009"

11. As above but using estimate of 45% of multifamily buildings in Minnesota having central cooling (based on data from "Table HC7. Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to MN air conditioning prevalence compared to US average);

Document Revision History:

Version / Description	Author	Date
1.0 New measure	FES	1.17.14
1.1 Minor revisions – table references, changed “residential” to “single family” where applicable, revised example description to specify A/C presence	JP	1.21.14
1.2 Simplified Table 3 (base/efficient wattage and incremental costs table), incorporated Xcel Energy approved baseline wattages in Table 3 reflecting gradual depletion of traditional incandescent lighting from the market under EISA	JP	2.5.14
1.3 Modified building type descriptions to clarify multifamily	JP	3.12.14

Residential Lighting - ENERGY STAR CFL Fixtures

Version No. 2.3

Measure Overview

Description: ENERGY STAR CFL Fixtures replace less efficient incandescent fixtures in retrofits or new construction. Fixtures are hardwired and use pin-based lamps.

Actions: Replace on Failure, Replace Working, New Construction
Target Market Segments: Residential, Commercial
Target End Uses: Lighting

Applicable to: Single family, duplex, townhome and multifamily (3+ unit) customers

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = (kW_Base - kW_EE) x CF x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 9.4 years (Ref. 2)

Unit Participant Incremental Cost: See Table 3

Where:

kW_EE = Deemed average wattage efficient luminaire per Table 3

kW_Base = Deemed average wattage of baseline luminaire per Table 3

Hrs = Deemed annual operating hours from Table 2 based on building type.

PAF = Deemed Power Adjustment Factor per Table 3.

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in Table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting (Ref. 3).

Required inputs from customer/vendor: Space type (interior living quarters, multifamily* common areas, exterior/unconditioned space), HVAC System (heating only, heating & cooling, exterior/unconditioned space)

** Multifamily includes 3+ unit buildings*

Example:

Install a CFL to replace an incandescent lamp in a single family home

*kWh = (0.106-0.034) * 938 *1.075 = 72.60 kWh*

*kW = 0.095 *(0.106-0.034) * 1.248 = 0.0085 kW*

*Dth/year = (0.106-0.034) * 938 * -0.0029 = -0.196 Dth/year*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)	
Space Type	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only or Heating & Cooling	Reference
Interior Living Quarters	1.00	1.248	1.00	1.075	-0.0029	3
Multifamily Common Areas	1.00	1.248	1.00	1.075	-0.0029	3
Exterior/Uncond. Space	1.00	1.00	1.00	1.00	0	3
Interior Living Quarters - Cooling Unknown	1.00	1.16	1.00	1.048	-0.0019	11
Multifamily Common Areas - Cooling Unknown	1.00	1.11	1.00	1.034	-0.0013	12

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 4 and 8) and Annual Operating Hours by Building Type (see table for references)

Space Type	CF	Hrs	Reference
Interior Living Quarters	9.5%	938	5
Multifamily Common Areas	75%	5,950	6
Exterior/Unconditioned Space	0%	1,825	5

Table 3: Fixture Wattage (Ref. 7 and 10) and Costs (Ref. 9)

Retrofit Category	Existing Device	Replacement Device	kW_base	kW_EE	Incremental Cost
Residential CFL Fixture	Average Incandescent fixture	Average ENERGY STAR replacement fixture	0.1060	0.0340	$40

Methodology and Assumptions:

The assumptions tab summarizes the average wattages used for the kW_base and kW_EE based on ENERGY STAR's current qualified product list. The baseline wattage is assumed to be approximately 4 times the efficient wattage of the fixture.

The option to collect the existing wattage and efficient wattage is available to input customer specific values in the algorithm. Use the average values provided if the existing and/or efficient wattages were not provided.

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Notes:

See assumptions tab for more information on the wattages used. Baseline incandescent lamp wattages are decreased through 2014 based on EISA 2007 legislation. Torchieres. Section 135(c) of EPACT 2005 amends section 325 of EPCA to add subsection (x) setting standards for torchieres. Torchieres manufactured on or after January 1, 2006, shall consume not more than 190 watts of power, and shall not be capable of operating with lamps that total more than 190 watts.

References:

1. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08 (range from 2-10, 9.4 years was selected)

2. Measure life: 9.4 years (calculated), based on 10,000 hour average lamp life

3. Calculated through energy modeling by FES 2012

4. Based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation. “ComEd Residential Energy Star Lighting Program Metering Study: Overview of Study Protocols” http://www.icc.illinois.gov/downloads/public/edocket/303835.pdf
“Memo RE: Lighting Logger Study Results – Version 2, Date: May 27, 2011, To: David Nichols and ComEd Residential Lighting Interested Parties, From: Amy Buege and Jeremy Eddy; Navigant Evaluation Team” http://www.icc.illinois.gov/downloads/public/edocket/303834.pdf

5. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 7.5 based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation.

6. Multifamily common area lighting assumption is 16.3 hours per day (5950 hours per year) based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, and November 2010.

7. ENERGY STAR Light Fixtures Product List - accessed 8/29/2012 and summarized in the Assumptions tab.
http://downloads.energystar.gov/bi/qplist/Lamps_Qualified_Product_List.xls?1c46-c682

8. Coincidence factor is based on healthcare/clinic value (used as proxy for multifamily common area lighting with similar hours of use) developed using Equest models for various building types averaged across 5 climate zones for Illinois for the following building types.

9. Study of costs for both incandescent and fluorescent fixture options determined an average incremental cost of $40 for ENERGY STAR fixtures.

10. CFL METERING STUDY FINAL REPORT, Prepared for: Pacific Gas & Electric Company, San Diego Gas & Electric Company, Southern California Edison Company, 2005

11. As above but using estimate of 64% of single family and multifamily in unit buildings in Minnesota having central cooling (based on data from “Table HC7.1 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009”

12. As above but using estimate of 45% of multifamily buildings in Minnesota having central cooling (based on data from “Table HC7. Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to MN air conditioning prevalence compared to US average);

Document Revision History:

Version / Description	Author	Date
2) Create ENERGY STAR CFL Fixture measure	FES	8/31/2012
2.1) Added to description to specify that fixtures are hardwired and use pin-based lamps	JP	4/2/2013
2.1) Revised space type names, moved wattages to Optional Inputs from Customer/Vendor	JP	4/2/2013
2.2) Added new construction to action types and commercial to market segments (for multifamily participation in residential lighting program), removed existing and efficient wattages from optional inputs for consistency with other residential lighting measures and because incremental cost is deemed.	JP	3/6/2014
2.3) Modified space types to clarify multifamily	JP	3/12/2014

Residential Lighting - LED Holiday Lighting

Version No. 2.8

Measure Overview

Description: This measure includes replacement of failed or working incandescent holiday light strings with new LED holiday light strings

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential, Commercial
Target End Uses: Lighting

Applicable to: residential customers in single-family homes, duplexes, and townhomes. Also available to commercial customers.

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Q x N x Hrs

Unit Peak kW Savings = 0

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 8 (Ref. 1)

Unit Participant Incremental Cost = $10 (Ref. 3)

Where:

kW_EE = Stipulated wattage per light (kW per light) for efficient light string. See Table 1.

kW_Base = Stipulated wattage per light (kW per light)from baseline light string. See Table 1.

Q = Number of light strings

N = Number of lights in string

Hrs = Estimated annual operational hours per year of the fixture = 150 (Ref. 4);

Required from Customer/Contractor: Number of light strings, number of lights per string, type of each lighting string (C7, C9, mini).

Example:

A customer bought (4) 70-light LED mini holiday light strings.

Unit kWh Savings per Year = (0.00045 - 0.000043) x 70 x 4 x 150 = 17.1 kWh

Unit Peak kW Savings per Year = 0 kW

Deemed Input Tables:

Table 1: Post-and Pre-retrofit Wattages per Light (Ref. 2, 5)

Post-retrofit Fixture	kW_EE	Pre-retrofit Fixture	kW_Base
LED Mini Holiday Lights	0.000043	Incandescent Mini Holiday Lights	0.000450
LED C9 Holiday Lights	0.002000	Incandescent C9 Holiday Lights	0.007000
LED C7 Holiday Lights	0.000480	Incandescent C7 Holiday Lights	0.006000

Methodology and Assumptions:

Light strings are assumed to be operating during winter (HVAC cooling factors and kW savings ignored)

Any potential gas savings is assumed to be negligible; due to a number of installations being in unheated space.

Hours are based on 5 hours per day, 30 days per year.

Light strings are assumed to be operating during non-peak hours; CF = 0

Notes:

ENERGY STAR criteria for Decorative Light Strings is: "Products must meet stringent efficiency (under 0.2W per bulb) and quality (3-year warranty, protection against over-voltage, maintained light output) requirements.

If desired, the baseline and proposed wattages can be prorated for light strings of different lengths (i.e. 50-light and 100-light strings)

References:

1. Engineering judgment based on 50% of DEER measure life value (16 years).

2. Based on a 70-light string; Pacific Gas & Electric document "Light up the holidays and save", November 2009.

3. State of Ohio Energy Efficiency Technical Reference Manual (TRM) for Ohio State Senate Bill 221, October 2009. Page 59.

4. Holiday Lights: LED and Fiber Optics, November 2007. Energy Ideas Clearinghouse.

5. Technical Reference Manual State of Pennsylvania Act 129 Energy Efficiency and Conservation Program & Act 213 Alternative Energy Portfolio Standards, June 2014 page 174.

Documentation Revision History:

Version / Description	Author	Date
1. Original from Nexant with extraneous tabs hidden	Joe Plummer, DER	
2. Updated baseline wattages and added source	Franklin Energy Services	7/23/2012
2.1 Added example	Franklin Energy Services	7/23/2012
2.2 Removed cooling savings factors from the algorithms as this measure primarily occurs during the heating season or outdoors.	Franklin Energy Services	7/23/2012
2.3 Corrected algorithm to read "(kW_Base - kW_EE)" instead of "(kW_EE - kW_Base)"	Franklin Energy Services	7/23/2012
2.4 Removed the heating penalty factor	Franklin Energy Services	7/23/2012
2.5 Updated measure cost	Franklin Energy Services	7/23/2012
2.6 Minor revisions to header information	JP	4/3/2013
2.6 Incorporated deemed hours and CF in input descriptions and deleted Table 3	JP	4/3/2013
2.7 Added C7 and C9 lights. Corrected measure life	FES	2/27/2014
2.8 Retained old measure life of 8 years, added light type to Required inputs, eliminated old Table 1 (deemed wattages for 70-light strings of minis), changed kW algorithm to kW = 0 since CF = 0, updated example	JP	7/8/2014

Residential Hot Water – Electric Water Heater Jacket Insulation

Version No. 2.0

Measure Overview

Description: This measure includes installing a water heater blanket on an electric water storage water heater.

Actions: Retrofit
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family, duplexes and townhomes with electric water heaters

Algorithms

Unit kWh Savings per Year = ((U_base x A_base - U_insul x A_insul) x (T_hot - T_ambient) x Hours) / Eff / ConversionFactor

Unit Peak kW Savings = Unit kWh Savings Per Year / Hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 5 (Ref. 1)

Unit Participant Incremental Cost = $20 (Ref. 5)

Where:

U_base = R-12; heat transfer coefficient of water heater without insulation jacket (Ref. 1)

U_insul = R-18; heat transfer coefficient of water heater with insulation jacket (Ref. 6)

A_base = Surface area of uninsulated water heater (Table 1)

A_insul = Surface area of insulated water heater (Table 1)

T_hot = 120°F; (Ref. 3)

T_ambient = 60°F (Ref. 7)

Eff = See Table 1; Minimum Energy Factor = 0.67 - 0.0019 x (Tank Size in Gallons)

Hours = 8,766 hours

ConversionFactor = 3,412 Btu/kWh

Required from Customer/Contractor: project location (county), water heater size in gal, water heater fuel type

Example:

A customer in Zone 2 installed an insulation jacket on their 50-gallon water heater.

Unit kWh Savings per Year = ((1/12 x 24.99 ft2 - 1/18 x 27.06 ft2) x (120°F - 60°F) x (8,760 hours)) / 0.90 EF / 3,412 Btu/kWh = 99.1 kWh

Unit Peak kW Savings= 99.1 kWh / 8,760 hours = 0.011 kW

Deemed Input Tables:

Table 1: Energy Factors and Surface Areas, ft^2 (Ref. 1)

Water Heater Size	Eff	A_bare	A_insul
40-gallon tank	0.92	23.18	25.31
50-gallon tank	0.90	24.99	27.06
80-gallon tank	0.86	31.84	34.14

Methodology and Assumptions:

The algorithm is based on the IL TRM, but assumes a 2", R-6 water heater blanket.

Notes:

If assuming 46 gal/day hot water usage, the savings in the example comes out to about 4% of the overall DHW energy

There is no current standard for level of insulation necessary for new or existing water heaters.

New water heaters are required to meet Energy Factor requirements, but are not required to meet a specific insulation level.

References:

1. Illinois Technical Reference User Manual, 6/1/2012. Pages 429-432.

2. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules* http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

3. Recommended value on DOE website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Consistent with other DHW measures.

4. Measure life source: California Measurement Advisory Committee (CALMAC) Protocols, Appendix F (www.calmac.org/events/protocol.asp).

5. Incremental cost: assumed same cost as water heater blanket; Assumed $20 based on online pricing search. Franklin Energy Services.

6. Assumed an R-6 water heater wrap (2" thickness); Most available according to internet research.

7. The ambient temperature is based on the water heaters being located in the basement.

Documentation Revision History:

Version / Description	Author	Date
1. Based on original from Nexant, cleaned up and reformatted	Joe Plummer	
2. Added algorithms based on IL TRM (Ref. 1)	Franklin Energy Services	7/31/2012

Residential Hot Water - Drainpipe Heat Exchanger with Electric Water Heater

Version No. 2.4

Measure Overview

Description: This measure includes installing a drainpipe heat exchanger to a residential or multi-family building to recover heat from heated water going down the building's drain.

Actions: Modify
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters.

Algorithms

Unit kWh Savings per Year = EnergyToHeatWater / Eff x SavingsFactor / ConversionFactor

Unit Peak kW Savings = Unit kWh Savings per Year / 8,766

Unit Dth Savings per Year = EnergyToHeatWater / Eff x SavingsFactor / ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 20 (Ref. 1)

Unit Participant Incremental Cost = $742 (Ref. 1)

Where:

EnergyToHeatWater = SpecificHeat x Density x Gal/Day x 365.25 Days/Year x (Tset - Tcold)

SpecificHeat = 1.0 btu/(lb x °F)

Density = 8.34 lbs/gal

Gal/Day = See Table 2; Average gallons per day of hot water usage (gal/day)

Tset = 120 °F (Ref. 4)

Tcold = Average groundwater temperature per Table 1 (Ref. 3)

Eff = Energy Factor of water heater (provided by customer/contractor)

SavingsFactor = 0.25 (Ref. 2)

ConversionFactor = 3,412 Btu/kWh (electric water heater) or 1,000,000 Btu/Dth (gas water heater)

Required from Customer/Contractor: Confirmation of electric water heater, water heater efficiency (EF), building type (single family or multi family*), project location (county).

** Includes buildings with 2+ units and townhomes*

Example:

A single-family customer in Zone 1 has installed a drain pipe heat exchanger to recover wasted energy from the house's drain line. Their electric water heater has an EF of 0.92..

EnergyToHeatWater = (1 Btu/lb°F) x (8.34 lbs/gal) x (52.7 gal/day) x (365.25 days/yr) x (120°F - 46.5°F) = 11,799,245 Btu/yr

Unit kWh Savings per Year = (11,799,245 Btu/yr) / (0.92) x (25%) / (3,412 Btu/kWh) = 940 kWh

Unit Peak kW Savings = 940 kWh / 8,766 h = 0.107 kW

Deemed Input Tables:

Table 1: Average groundwater temperatures (Ref. 3)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3

Table 2: Daily Hot Water Usage by Building Type

Building Type	Daily Gal/person (Ref. 5)	Num_People (Ref. 6)	Total Daily Hot Water Use (gal/day)
Single-family	20.4	2.59	52.7
Multi-family	18.7	2.17	40.5

Notes:

There are no current efficiency standards for this technology.

References:

1. State of Ohio Energy Efficiency Technical Reference Manual, 2010. Prepared by Vermont Energy Investment Corporation. Page 78.

2. Drain pipe heat exchange savings estimates are based on study findings reported in a communication from J. J. Tomlinson, Oak Ridge Buildings Technology Center, to Marc LaFrance, DOE Appliance and Emerging Technology Center, DOE, August 24, 2000, suggesting 25 to 30% of water heating consumption savings potential. The lower end of the savings scale was chosen for this report, assuming ideal installation for the study.

3. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules*

http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

4. "Lower Water Heating Temperature for Energy Savings," Department of Energy website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Accessed 7/26/12. The webpage referenced by the link has since changed and is no longer relevant.

5. Interpolated values from Table 38, Ohio Technical Reference Manual. October 15, 2009. Page 52.

6. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates)* for the state of MN.

http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=tabl

Documentation Revision History:

Version / Description	Author	Date
1. Derived from ResidentialElectricDHW_v03.2 and ResidentialGasDHW_v03.2 which were based on Nexant's original spec.	Joe Plummer, DER	
2. Updated the groundwater temperatures, see "Water Temps" tab	Franklin Energy Services	7/23/2012
2.1 Added example	Franklin Energy Services	7/23/2012
2.2 Updated the measure cost	Franklin Energy Services	7/23/2012
2.3 Changed action to Modify, changed “electric or gas water heater” to “confirmation of electric water heater” under required inputs, changed annual hours from 8,760 to 8,766, updated example for electric instead of gas	JP	11/24/2013
2.4 Added building type to required inputs, added definition of multifamily	JP	3/18/2014

Residential Hot Water – Electric Water Heater

Version No. 4.2

Measure Overview

Description: This measure includes replacement of failed or working storage-type electric resistance water heaters in residential and multifamily buildings, as well as installation of electric resistance water heaters in new construction.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters

Algorithms

Unit kWh Savings per Year = Energy to Heat Water x (1/EF_minimum – 1/EF_efficient) / ConversionFactor

Unit Peak kW Savings = Unit kWh Savings / 8,760 hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 (Ref. 3)

Unit Participant Incremental Cost = See Table 4

Where:

EnergyToHeatWater = Specific Heat x Density x Gal_Person x People x 365 Days/Year x (Tset – Tcold)

SpecificHeat = 1.0 btu / (lb x °F)

Density = 8.34 lbs / gal

Gal_Person = See Table 2; Daily hot water usage per person

People = See Table 3; number of people per household

Tset = 120 F (Ref. 7)

Tcold = Average groundwater temperature per Table 1

EF_Minimum = 0.97 – 0.00132 x (Tank Size in Gallons)

EF_Efficient = Efficiency (energy factor) of new water heater (0-1)

ConversionFactor = 3,412 Btu/kWh

Required from Customer/Contractor: confirmation of electric water heater, tank size in gallons, new water heater efficiency (EF), single-family or multi family*, project location (county)

** Includes buildings with 2+ units and townhomes*

Example:

A single-family customer in Zone 2 has installed a new 105-gallon electric resistance water heater with an EF of 0.91 to replace their previous less efficient electric resistance storage water heater.

EF_Minimum = 0.97 – (0.00132 x 105) = 0.83

Energy To Heat Water = (1 Btu/lb°F) x (8.34 lbs/gal) x (20.4 gal/person) x (2.59 people) x (365 d/yr) x (120°F - 49.1°F) = 11,403,419 Btu/yr

Unit kWh Savings per Year = (11,403,419 Btu/yr) x (1/0.83 - 1/0.91) / (3,412 Btu/kWh) = 354 kWh

Unit Peak kW Savings = 354 kWh / 8,760 h = 0.040 kW

Deemed Input Tables:

Table 1: Average groundwater temperatures (Ref. 4)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3

Table 2: Daily Hot Water Usage per Person (Ref. 8)

Application	(Gal/day)/person
Single-Family	20.4
Multi-Family*	18.7

** Includes buildings with two or more units and townhomes*

Table 3: People per Household (Ref. 9)

Application	Num_People
Single-Family	2.59
Multi-Family*	2.17

** Includes buildings with two or more units and townhomes*

Table 4: Incremental Cost by Type (Ref. 4)

Type of Water Heater	Incremental Cost
High Efficiency Electric Storage	$104

Notes

Table 5: Current Equipment Standards, effective for products manufactured from January 20, 2004 through April 15, 2015 (Ref. 5)

Type of Equipment	Energy Factor
Electric Water Heater	0.97 - (0.00132 x Rated Storage Volume in gallons)

Table 6: Future Equipment Standards, effective for products manufactured on or after April 16, 2015 (Ref. 6)

Type of Equipment	Energy Factor
Electric Storage Water Heaters, ≤ 55 gallons	0.960 - (0.0003 x Rated Storage Volume in gallons)
Electric Storage Water Heaters, > 55 gallons	2.057 - (0.00113 x Rated Storage Volume in gallons)

References

1. Daily hot water usage is based on CEE's tankless water heater field study in Mpls/St. Paul (2008-2010); Supported by Focus on Energy's Residential Deemed Savings Review, page 4.

2. US DOE Building America Program. Building America Analysis Spreadsheet, Standard Benchmark DHW Schedules http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

3. Incremental water heater costs, water heater lifetime from NW Council-RTF Residential DHW-Efficient Tanks deemed savings, v 2.0

4. Values are from DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Tables 8.2.13-14, 8.2.16 (http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf). The values are interpreted with explanation in the "Cost Info" tab of this worksheet.

5. Title 10, Code of Federal Regulations, Part 430 - Energy Conservation Program for Consumer Products, Subpart C - Energy and Water Conservation Standards and Their Effective Dates. January 1, 2010

6. Energy Conservation standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters: Final Rule, Federal Register, 75 FR 20112, April 16, 2010.

7. "Lower Water Heating Temperature for Energy Savings," Department of Energy website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Accessed 7/26/12.

8. Interpolated values from Table 38, Ohio Technical Reference Manual. October 15, 2009. Page 52.

9. U.S. Census Bureau, Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates) for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer, DER	
2.0 Updated the groundwater temperatures	FES	7/23/2012
2.1 Added example	FES	7/23/2012
2.2 Amended description, measure requirements and EF_Efficient	FES	7/23/2012
2.3 Updated the incremental costs	FES	7/23/2012
3.0 Updated the hot water usage	FES	8/6/2012
4.0 Updated measure lifetimes for tankless water heaters	FES	3/20/13
4.1 Removed heat pump water heaters as more information is needed on interactive effects with HVAC system; updated example.	JP	2/7/14
4.2 Removed “owner-occupied” and “renter-occupied” from single-family and multi-family, respectively, in Tables 2 and 3. Added footnotes clarifying multi-family definition. Corrected typo in example.	JP	3/11/14

Residential Hot Water – Electric Water Heater Setback

Version No. 3.2

Measure Overview

Description:

This measure involves turning the water heater set point temperature to 120°F on residential storage-type water heaters, both gas and electric. The action must be performed by a utility representative on site during a home energy audit or other home visit.

The existing temperature set point is assumed to be 130°F.

Actions: Operations and Maintenance
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters

Algorithms

Unit kWh Savings per Year = SpecificHeat x Density x Gal_Person x People x 365.25 x (Tset - Tin) x Savings_Factor/ Eff / ConversionFactor

Unit Peak kW Savings = Unit kWh Savings per Year / 8,766 hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 2 (Ref. 2)

Unit Participant Incremental Cost = $0

Where:

SpecificHeat = 1.0 btu / (lb x °F)

Density = 8.34 lbs / gal

Gal_Person = See Table 2; Daily hot water usage per person

People = See Table 3; Number of people per household

Tset1 = 130 °F (assumed average starting temperature)

Tin = Average groundwater temperature per Table 1

Eff = 0.92 (2004 Federal minimum Energy Factor for 40 gal tank = 0.97 - 0.00132 x 40)

ConversionFactor = 3,412 Btu/kWh (electric water heater) or 1,000,000 Btu/MMBtu (gas water heater)

Savings_Factor = 4% (Ref. 3)

Required from Customer/Contractor: confirmation of electric water heater, project location (county), single-family or multi-family*

** Includes buildings with 2+ units and townhomes*

Example:

A direct install team reduces the set point of an electric water heater in a single-family home in Zone 1.

kWh savings = (1.0 Btu/lb°F) x (8.34 lb/gal) x (20.4 gal/day/person) x (2.59 people) x (365.25 day/yr) x (130°F - 46.5°F) x 4% / (0.92) / (3,412 Btu/kWh) = 171 kWh

kW savings = (171 kWh) / 8,766 hours = 0.020 kW

Deemed Input Tables:

Table 1: Average groundwater temperatures (Ref. 4)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3

Table 2: Daily Hot Water Usage per Person (Ref. 6)

Location	Gal/day/person
Single-Family	20.4
Multi-Family*	18.7

** Includes buildings with 2+ units and townhomes*

Table 3: People per Household (Ref. 7)

Application	Num_People
Single-Family	2.59
Multi-Family*	2.17

** Includes buildings with 2+ units and townhomes*

Methodology and Assumptions:

The savings from lowering the temperature setpoint 10°F is 3% to 5% of the overall domestic hot water energy. (Ref. 3)

The existing temperature is assumed to be 130°F (Ref. 5)

Notes:

There are no current energy standards for this measure.

The previous algorithm assumed that all hot water uses are done at max temperature, when in reality only a few are (i.e. clothes washer, dishwasher, misc. cleaning, etc.). The result of this was that the savings was being overestimated (i.e. 446 kWh, resulting in ~13% overall DHW savings). The IL TRM however, only accounts for the aforementioned uses and ignores the reduction in standby losses by lowering the delta T. The result of this is that the savings is underestimated (i.e. 49 kWh). The DOE estimates a savings that is between these two values. The savings value given by DOE estimates are supported by Ref. 2 (Efficiency Vermont TRM).

The excel algorithms yield a savings of 158 kWh and 0.84 Dth, which is within 4% of the values for Zone 1-single-family applications. The difference in savings will increase in zones 2 and 3 and in multi-family applications.

References:

1. Daily hot water usage is based on CEE's tankless water heater field study in Mpls/St. Paul (2008-2010); Supported by Focus on Energy's Residential Deemed Savings Review, page 4.

2. Efficiency Vermont Technical Reference User Manual (TRM), 2/19/2010. Page 409. This value is supported by the Illinois Technical Reference User Manual, 2012.

3. Average of 3-5% savings values on DOE website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Accessed 7/2

4. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules*

http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

5. Franklin Energy Services internal value.

6. Interpolated values from Table 38, Ohio Technical Reference Manual. October 15, 2009. Page 52.

7. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Commnity Survey 1-Year Estimates)* for the state of MN.

http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table

Documentation Revision History:

Version / Description	Author	Date
1. Originally part of ResidentialGasDHW_v03.2 which was derived from Nexant spec; changed algorithm to assume an average starting and final temperature rather than using an unsupported savings factor	Joe Plummer, DER	
2.0 Updated algorithm to use Savings_Factor of 4%	Franklin Energy Services	7/26/2012
2.1 Updated measure lifetime per Ref. 2	Franklin Energy Services	7/27/2012
3.0 Updated the hot water usage to be consistent with the hot water heater measure algorithm	Franklin Energy Services	8/6/2012
3.1 Changed “electric or gas water heater” to “confirmation of electric water heater” under required inputs, changed annual hours from 8760 to 8766	JP	11/25/2013
3.2 Added footnotes clarifying multifamily definition. In kWh algorithm, replaced Gal/Day with Gal_Person x People. Corrected example calculation.	JP	3/18/2014

Residential Hot Water - Faucet Aerator (1.5 gpm) with Electric Water Heater

Version No. 3.5

Measure Overview

Description: This measure includes replacing an existing faucet aerator with low-flow aerator.

Actions: Replace Working
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters

Algorithms

Unit kWh Savings per Year = WaterSaved x Density x SpecificHeat x (Tfaucet – Tcold) / ReEff / ConversionFactor

Unit Peak kW Savings = Unit kWh Savings per Year / 8,766 hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 1)

Unit Participant Incremental Cost = $6.70 (Ref. 6)

Where:

WaterSaved = Flow_diff x Vmin x (Num_People) x 365 days/year

Flow_diff = 1.0 GPM (i.e. 2.5 GPM replaced with 1.5 GPM)

Vmin = 1.125 minutes; the number of minutes of faucet use per adjusted number of bedrooms per day (an average of the following values: 1.5 minutes (kitchen) and 0.75 minutes (bathroom)) (Ref. 2)

Num_People = Number of people per household per Table 2

SpecificHeat = 1.0 btu / (lb x °F)

Density = 8.34 lbs / gal

Tfaucet = 80°F; Temperature of typical faucet usage (Ref. 2)

Tcold = Average groundwater temperature per Table 1 (Ref. 4)

ReEff = 0.98; recovery efficiency (electric water heater) (Ref. 7)

ConversionFactor = 3,412 Btu/kWh (electric water heater)

Required from Customer/Contractor: confirmation of electric water heater, building type (single family or multi family*), project location (county)

** Includes buildings with 2+ units and townhomes*

Example:

Direct installation of a 1.5 GPM faucet aerator in an apartment with electric water heat located in Zone 1.

WaterSaved (gal/yr) = (1.0 gal/min) x (1.125 min) x (2.17 people) x 365 days/year = 891 gallons saved per year

Unit kWh Savings per Year = (891 gal) x (8.34 lbs/gal) x (1.0 Btu/lb°F) x (80°F – 46.5°F) / 0.98 /3,412 Btu/kWh = 74.4 kWh saved

Unit Peak kW Savings = 74.4 kWh / 8,766 h = 0.008 kW

Deemed Input Tables:

Table 1: Average groundwater temperatures (Ref. 4).

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3

Table 2: People per Household (Ref. 3).

Application	Num_People
Single-Family	2.59
Multi-Family*	2.17

** Includes buildings with 2+ units and townhomes*

Methodology and Assumptions:

Uses algorithms from Efficiency Vermont TRM (Ref. 2)

The “BR + 1” from Ref. 2 is assumed to equal the number of people per household or unit; People per household will be used instead of BR + 1.

Notes:

The current standard for kitchen and bathroom aerators is 2.2 GPM, effective 1/1/1994. (Ref. 5)

FOE uses 8 therms/187 kWh for Commercial applications

ActOnEnergy TRM has 82 kWh, 6.1 therms, and 15 years

IL TRM uses 1.89 therms/ 42 kWh

NY TRM has 314 kWh, 17 therms

Ohio TRM (VEIC) 2010 uses 24.5 kWh / .109 MMBtu

References:

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values. http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.

2. Efficiency Vermont Technical Reference User Manual, 2/19/2010.

3. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates)* for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table

4. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules* http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

5. Title 10, Code of Federal Regulations, Part 430 – Energy Conservation Program for Consumer Products, Subpart C – Energy and Water Conservation Standards and Their Effective Dates. January 1, 2010

6. 2008 Database for Energy-Efficient Resources, Cost Values and Summary Documentation (updated 6/2/2008 – NR linear fluorescent labor costs typo) http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.

7. State of Illinois Energy Efficiency Technical Reference Manual, Page 132-139. July 18, 2012.

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer, DER	
2. Revised formatting and algorithms	Franklin Energy Services	7/27/2012

2. Update the measure life and measure cost	Franklin Energy Services	7/27/2012
3. Corrected Energy Factor equations	Franklin Energy Services	3/20/2013
3.1 Changed action from Direct Install to Replace Working	Joe Plummer, DER	4/5/2013
3.2 Removed extra multiplication sign following Eff in savings algorithms	Joe Plummer, DER	8/28/2013
3.3 Changed “electric or gas water heater” to “confirmation of electric water heater” under required inputs, changed efficiency (0.92) to recovery efficiency (0.98) and updated example accordingly, changed annual hours from 8,760 to 8,766	JP	11/25/13
3.4 Added residence type (single family or multi family) to required inputs	JP	1/3/14
3.5 Removed “owner-occupied” from single-family and “renter-occupied” from multi-family categories in Tables 2 and 3, added footnotes clarifying multifamily definition.	JP	3/11/14

Residential Hot Water - Low Flow Showerheads (1.5 gpm) with Electric Water Heater

Version No. 3.3

Measure Overview

Description: This measure involves replacing a standard showerhead with a low flow showerhead.

Actions: Replace Working
Target Market Segments: Residential: Single-family and Multi-family
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters

Algorithms

Unit kWh Savings per Year = WaterSaved x Density x SpecificHeat x (Tshower - Tcold) / ReEff / ConversionFactor

Unit Peak kW Savings = Unit kWh Savings per Year / 8,766 hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 5)

Unit Participant Incremental Cost = $12 (Ref. 4)

Where:

WaterSaved = Flow_reduction x ShowerWater x Num_People x SPCD x 365 days/year / SPH

Flow_reduction = 40% (i.e. 2.5 GPM replaced with 1.5 GPM; (2.5-1.5)/2.5 = 0.40)

ShowerWater = 17.2 gallons; daily hot water use per shower per person (Ref. 3)

Num_People = Number of people per household per Table 2

SPCD = 0.75; Showers per capita per day (Ref. 4)

SPH = Showerheads per Household per Table 3

SpecificHeat = 1.0 Btu/(lb°F)

Density = 8.34 lbs / gal

Tshower = 105°F; Temperature of typical shower usage (Ref. 2)

Tcold = Average groundwater temperature per Table 1

ReEff = 0.98; recovery efficiency (electric water heater) (Ref. 7)

ConversionFactor = 3,412 Btu/kWh (electric water heater)

Required from Customer/Contractor: confirmation of electric water heater, building type (single-family or multi-family*), project location (county)

** Includes buildings with 2+ units and townhomes*

Example:

Direct installation of a low-flow showerhead in an apartment with electric water heat located in Zone 3.

WaterSaved (gal/yr) = (40%) x (17.2 gal/person) x (2.17 people/household) x 0.75 SPCD x 365 days/year / 1.3 SPH = 3,144 gallons saved per year

Unit kWh Savings per Year = (3,144 gal) x (8.34lbs/gal) x (1 Btu/lb°F) x (105°F - 51.3°F) / 0.98 / 3,412 Btu/kWh = 421 kWh saved

Unit Peak kW Savings = 421 kWh / 8,766 hours = 0.048 kW

Deemed Input Tables:

Table 1: Average groundwater temperatures (Ref. 2).

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3

Table 2: People per Household (Ref. 1).

Application	Num_People
Single-Family	2.59
Multi-Family*	2.17

** Includes buildings with 2+ units and townhomes*

Table 3: Showerheads per Household (Ref. 4).

Application	SPH
Single-Family	1.79
Multi-Family*	1.30

** Includes buildings with 2+ units and townhomes*

Methodology and Assumptions:

Algorithm is based on the Illinois TRM (Ref. 4), but has been modified with regard to existing water usage estimation. The original IL TRM calculation was estimating fairly high pre-retrofit water usages, so 11.6 gal/day (Ref. 3) has been used in an effort to temper the results.

Notes:

The current flow standard for showerheads is 2.5 GPM (Ref. 6)

References:

1. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates)* for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table

2. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules*

http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

3. Mayer P., DeOreo W., et.al. 1999. Residential end Uses of Water, American water Works Association Research Foundation.

4. Illinois Technical Reference Manual, 6/1/12. Pages 419-426.

5. Table C-6, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. Evaluations indicate that consumer dissatisfaction may lead to reductions in persistence, particularly in Multi-Family,

http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf

6. Title 10, Code of Federal Regulations, Part 430 - Energy Conservation Program for Consumer Products, Subpart C - Energy and Water Conservation Standards and Their Effective Dates. January 1, 2010

7. State of Illinois Energy Efficiency Technical Reference Manual, Page 132-139. July 18, 2012.

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer	
2. Changed algorithm per IL TRM and modified the HW usage estimates	Franklin Energy Services	7/31/2012
2. Changed Measure Lifetime from 7 to 10	Franklin Energy Services	7/31/2012

3. Updated ShowerWater description to read "shower water..." instead of "hot water..."	Franklin Energy Services	1/4/2013
3.1 Changed Action type from Direct Install to Replace Working	Joe Plummer	4/8/2013
3.1 Added residence type to list of required inputs from customer/vendor	Joe Plummer	4/8/2013
3.1 Changed description of Tshower from "typical faucet usage" to "typical shower usage"	Joe Plummer	4/8/2013
3.1 Changed "Required Inputs from Direct Installer" to "Required Inputs from Customer/Contractor"	Joe Plummer	4/8/2013
3.2 Changed “electric or gas water heater” to “confirmation of electric water heater” under required inputs, changed efficiency to recovery efficiency of 0.98 and updated example accordingly, changed annual hours to 8,766	JP	11/25/2013
3.3 Added footnotes clarifying multifamily definition	JP	3/18/2014

Residential Hot Water - Pipe Insulation with Electric Water Heater

Version No. 2.3

Measure Overview

Description: This measure includes installing pipe insulation on un-insulated piping of an electric water heating system.

Actions: Modify
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family, duplexes and townhomes with electric water heaters.

Algorithms

Unit kWh Savings per Year = (Qloss_base - Qloss_insul) x Hours x Length / ConversionFactor / Eff

Unit Peak kW Savings = Unit kWh Savings per Year / 8,766 hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 13 (Ref. 3)

Unit Participant Incremental Cost = $3.63 (Ref. 4)

Where:

Qloss_base = See Table 1 for values. Heat loss (Btu/ft) from bare piping; See "Btu per Foot" tab for explanation.

Qloss_insul = See Table 1 for values. Heat loss (Btu/ft) from insulated piping; See "Btu per Foot" tab for explanation.

T_hot = 120°F; (Ref. 2; to be consistent with other DHW measures)

T_ambient = 60°F (Ref. 1)

Eff = 0.92

Hours = 4,823 hours; Hours when outside air temperature is above building balance point. Heat loss from pipe is wasted. (Ref. 5)

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: length of pipe insulation (linear feet), confirmation of electric water heater

Example:

A customer installed R-2 insulation on one foot of un-insulated hot water piping

Unit kWh Savings per Year = (39.6 Btu/ft - 6.9 Btu/ft) x 4,823 hours x 1 ft. / 3,412 Btu/kWh / 0.92 = 50.2 kWh

Unit Peak kW Savings= 50.2 kWh / 8,766 hours = 0.0057 kW

Deemed Input Tables:

Table 1: Average Heat Loss Figures (Ref. 5)

Location	Avg. Heat Loss of Bare Pipe (Btu/ft)	Avg. Heat Loss of Insulated Pipe (Btu/ft)
Zone 1, 2, and 3	36.9	6.9

Methodology and Assumptions:

Pipes are assumed to be an equal mix of 1/2", 3/4" and 1" sizes.

Insulation is assumed to be R-2 pipe insulation.

Notes:

Section N1103.3 of the 2006 International Residential Code requires mechanical system piping that is capable of carrying fluids above 105 degrees F or below 55 degrees F to be insulated to a minimum of R-2.

References:

1. The ambient temperature is assumed to be 60°F, based on the estimated temperature of a basement where the water heater is assumed to be located.

2. "Lower Water Heating Temperature for Energy Savings," Department of Energy website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Accessed 7/26/12.

3. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values. http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.

4. 2008 Database for Energy-Efficient Resources, Cost Values and Summary Documentation (updated 6/2/2008 - NR linear fluorescent labor costs typo) http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.

5. Xcel Energy 2010-2012 CIP Triennial (Docket No. E, G002/CIP-09-198), Pages 470-477.

Document Revision History:

Version / Description	Author	Date
1. Based on original from Nexant, cleaned up and reformatted	Joe Plummer, DER	
2. Reformatted	Franklin Energy Services	7/26/2012
2.1 Updated the measure cost value/source	Franklin Energy Services	7/31/2012
2.2 Updated the measure lifetime from 15 to 13	Franklin Energy Services	7/31/2012
2.3 Changed Action to Modify, changed Table1 so that same heat loss figures apply to all zones, delete zip code from required inputs, added confirmation of electric water heater to required inputs, changed annual hours to 8,766	JP	11/24/13

Residential Load Management Technologies

Version No. 1.0

Measure Overview

Description: This measure includes the following residential load management technologies: A/C cycling, electric heat cycling, electric water heater curtailment, and electric thermal storage for space heating. Load management programs are primarily intended to reduce peak electrical demand and/or shift energy use to off-peak hours. Therefore, the primary impact is peak kW savings, though secondary kWh savings also result except from electric thermal storage.

Actions: Modify, Replace Working, Replace on Fail, New Construction
Target Market Segments: Residential
Target End Uses: HVAC, DHW

Applicable to: Residential customers in single-family homes

Algorithms

Unit kWh Savings per Year = (average # of events) x (kWh savings per event)

Unit Peak kW Savings = kW savings per event

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years (Ref. 2)

Unit Participant Incremental Cost = (Refer to Table 4)

Where:

Average # of events = average number of load control events during a typical year, provided by utility

kWh savings per event = modeled net kWh savings per load control event per installation, including snapback (refer to Tables 1-3.)

kW savings per event = modeled peak kW savings per load control event per installation (refer to Tables 1-3)

Required Inputs from Utility: Load control technology installed (A/C cycling, electric heat cycling, electric water heater curtailment, electric thermal storage for space heating), installation location (county), average number of load control events in a typical year

Optional Inputs from Utility: Cost of load control equipment, installation, and any metering costs

Example:

An A/C cycling device is installed at a single family home in Zone 3. Based on historical experience and load growth projections, the utility expects that on average, two load control events will occur in a typical year.

From Table 3:

Unit kWh Savings per Year = 2 x 0.71 = 1.42 kWh

Unit Peak kW Savings = 0.30 kW

Deemed Input Tables:

Table 1: Modeled kWh and kW savings per Load Control Event per Unit, Zone 1 (Ref. 1)

Technology	kWh Savings	Summer kW Savings	Winter kW Savings
A/C Cycling	0.01	0.07	0.00
Electric Heat Cycling	2.54	0.00	2.00
DHW Curtailment	0.58	0.54	0.76
Electric Thermal Storage	0.00	0.00	26.90

Table 2: Modeled kWh and kW savings per Load Control Event per Unit, Zone 2 (Ref. 1)

Technology	kWh Savings	Summer kW Savings	Winter kW Savings
A/C Cycling	0.65	0.23	0.00
Electric Heat Cycling	1.62	0.00	1.27
DHW Curtailment	0.43	0.49	0.76
Electric Thermal Storage	0.00	0.00	24.00

Table 3: Modeled kWh and kW savings per Load Control Event per Unit, Zone 3 (Ref. 1)

Technology	kWh Savings	Summer kW Savings	Winter kW Savings
A/C Cycling	0.71	0.30	0.00
Electric Heat Cycling	3.11	0.00	1.42
DHW Curtailment	0.40	0.60	0.84
Electric Thermal Storage	0.00	0.00	22.43

Table 4: Default Incremental Cost (Equipment plus Installation) by Technology

Technology	Incr. Cost	Ref.
A/C Cycling	$200	2
Electric Heat Cycling	$200	2
DHW Curtailment Summer	$200	2
DHW Curtailment Winter	$200	2
Electric Thermal Storage	$11,700	3, 4

Methodology and Assumptions

Current Smart Measure™ implementation of this measure on ESP® does not support winter kW savings at this time.

Default incremental costs include equipment and installation only. If the program includes meter installation, some portion of these costs should be included in a cost-effectiveness analysis.

Energy and demand impacts are based on simulation results by Michaels Energy using BEopt and EnergyPlus for a median residential home as defined in Ref. 1 in Zones 1, 2, and 3.

- A demand response event was simulated on July 15 and the air conditioning was cycled every 15 minutes during the event, which lasted for 7 hours, from 1 pm to 8 pm. A domestic water heater demand response event was also simulated on these homes on both winter (January 28) and summer peak days. The winter demand event occurred from 4 pm to 7 pm. TMY3 (typical meteorological year, third collection) weather data was used in all of the simulations using the designated cities for each climate zone (Minneapolis, Saint Cloud, Duluth). The summer event schedule was selected based on the data provided by the two utilities in this study, which showed that 1 pm to 8 pm was the most common control period. The winter event schedule was selected based on the fact that the IOU triggers events on winter afternoons and the G&T Co-op's website shows that their winter loads peak in the late afternoon and early evening hours. Although there are a variety of control methods, 50% cycling of air conditioners was used in this model because it is the most commonly used scheme in Minnesota. Load curtailment during the event was used for domestic water heaters, since that is the most common form of control for those systems, according to the websites of both of the utilities. July 15 was selected as the summer peak day because the TMY3 weather data showed that the outdoor air temperature was near the annual peak and the following day had a nearly identical temperature profile in order to properly evaluate snapback effects that may linger into the next day after a demand response event. (Ref. 1)
- January 28th was selected for the winter event (except in Minneapolis; see footnote) because it was a typical winter day in the TMY3 weather data and the following day's temperature profile was very similar.
-
- TMY3 data were used for all simulations. Duluth was selected for Zone 1; St. Cloud was selected for Zone 2; and Minneapolis was selected for Zone 3.

- A/C cycling
  - A load control event was simulated on July 15 between 1 pm and 8pm. The A/C was cycled every 15 minutes during the event.
- Domestic hot water (DHW) curtailment
  - Load control events were simulated on both winter (January 28 except for Zone 3) and summer (July 15) peak days. The winter demand event occurred from 4 pm to 7 pm. The summer demand event occurred from 1 pm to 8 pm.
  - The weather file data for Minneapolis on January 28 contained temperatures well below the design temperature for Minneapolis, while the other two climates had temperatures above their design temperatures on that data. Therefore, January 7 was selected for Minneapolis as a suitable replacement since it had a similar daily load profile at more typical temperatures with the following day (January 8) having a similar load profile.
- Electric heat cycling
  - Winter demand events occurred from 1 pm to 8 pm on January 28 except for Zone 3.
- Electric thermal storage
  - Days were selected to match the heating design temperatures in the TRM: Zone 1: -22F, Zone 2: -16.5F, Zone 3: -14.5F. In each case, the following day had a similar load profile.

References

1. Michaels Energy. *Demand Response and Snapback Impact Study.* August 2013. Prepared for Minnesota Department of Commerce, Division of Energy Resources under a grant through the Conservation Applied Research and Development (CARD) program. http://mn.gov/commerce/energy/topics/conservation/Applied-Research-Development/About-CARD.jsp, accessed February 11, 2014.
2. Average of pricing data from two Minnesota utilities. Includes equipment and installation costs. Does not include metering costs.
3. Efficiency Maine. *Energy Efficient Heating Options: Pilot Projects and Relevant Studies.* April 8, 2013. http://www.efficiencymaine.com/docs/EMT_Energy-Efficient-Heating-Options-Report_2013_4_8.pdf, accessed February 11, 2014. Average cost of electric thermal storage furnace = $13,000.
4. Web research on 2.11.14 and 2.12.14. Average price of 25 kW electric forced-air furnace = $1,300. Models: WMA60-25 (sold under names of Hamilton Home Products and Winchester 81,912 BTU 5 TON Multi-Position Electric Furnace); 21D25 (Nortron D-series 25 kW). Retailers: Northern Tool, Ecco Supply, Home Depot, Lowes.

Documentation Revision History

Ver.	Description	Author	Date
1.0	New measure	Joe Plummer, DER	2.11.14

Gas Efficiency Measures

C/I HVAC - Destratification Fan

Version No. 1.2

Measure Overview

Description: This measure analyzes the heating savings potential of destratification fans in new and existing buildings. Includes High Volume Low Speed and High Volume High Speed fans.

Actions: New Construction (addition on new or existing building)

Target Market Segments: Commercial & Industrial
Target End Uses: HVAC
Applicable to: All areas with less than a 50' ceiling height where stratification has been observed to be a problem.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (U x A x ΔT_C x HH x HrsPerDay/24) / η / 1,000,000

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years (ref 1)

Unit Participant Incremental Cost = See Table 1 (ref 2)

Where:

A = Area served by destratification fan. If unknown see Table 1. (ref 3)

HrsPerDay = Hours/day of operation. If unavailable assume 12. (ref.4)

HH = Heating Hours in season below 65°F. See Table 2. (ref. 5)

ΔT_C = Difference in ceiling air temperature (°F) in stratified and unstratified spaces. If unknown see Table 2 (ref. 6).

U = Average heat transfer coefficient for the roof (BTU / h · ft ^2 · °F). If unknown see Table 2. (ref. 7)

η = Efficiency of heating equipment. If unknown use 0.8 (ref. 8)

1,000,000 = Conversion factor for BTU to Dth

Required from Customer/Contractor: Ceiling height, area being destratified, project location (county)

Optional from Customer/Contractor: Heat transfer coefficient for roof, area being destratisfied in square feet, hours per day of fan operation in heating season, heating system efficiency

Example:

Install destratification fan per 1000 sq. ft. in 108,000 sq. ft. manufacturing facility operating on average 20 hours per day. The ceiling height is 25 ft. The building is located in Zone 3.

Dth Savings per Year = (0.08 x 108,000 x 10 x 20/24 x 6242) / 0.8 / 1,000,000 = 562 Dth

Table 1: Default square footages for fan applications and incremental costs

Ceiling Height (ft)	Destratification Area (ft^2) (ref. 3)	Incremental Cost / sq. ft. (ref. 2)
10 – 30	1000	$1.09
31 – 50	750	$1.45

Table 2: Ceiling Temperature differences, hours and U values

Zone #	ΔT_C (°F) (ref. 6)	Heating Hours (ref. 5)	U (ref. 7) BTU/h·ft^2·°F
Northern: #1	10	7066	0.08
Central: #2	10	6643	0.08
Southern: #3	10	6242	0.08

Methodology and Assumptions:

Assumed a noticeable stratification temperature is 10 °F or more.

Applicable to High Volume Low Speed and High Volume High Speed fans.

Assumes whole area is covered by stratification fans.

Notes:

ASHRAE Advanced Design Guide for Manufacturing Facilities recommends destratification fans for ASHRAE zones 5-8.

There is a kW and kWh penalty not addressed in these calculations.

References:

1. "Measured Life Report Residential and Commercial/Industrial Lighting and HVAC Measures", June 2007, by GDS Associates, Inc.pg. 1-3, modified to fan application and engineering judgment

2.”Technology Evaluation of Thermal Destratifiers and Other Ventilation Technologies", by Joel C Hughes, Naval Facilities Engineering Center, pg. 8, average of examples

3."Technology Evaluation of Thermal Destratifiers and Other Ventilation Technologies", by Joel C. Hughes, Naval Facilities Engineering Center, pg. 3, rounded values

4. Average number of occupied hours in day, FES.

5. National Climate Data Center - National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.

6. "Technology Evaluation of Thermal Destratifiers and Other Ventilation Technologies", by Joel C. Hughes, example 1 of measured ceiling temperatures normalized for HDD, FES

7. Composite U value for Deer Manufacturing Model modified to reflect lower U values, FES

8. Assumed standard combustion efficiency of heating equipment, FES

Documentation Revision History:

Version	Description	Author	Date
1.	New savings specification for retrofit/incorporation of destratification fans.	FES	8/1/2012
1.1	Changed statement "Assumed a noticeable stratification temperature is 5° or more" to "10° or more" per FES comment response, changed measure name, made some inputs optional per variable definitions, minor revisions	JP	2/12/2013
1.2	Corrected typos in algorithm, added heating system efficiency to optional inputs	JP	4/2/2014

C/I HVAC - Infrared Heater

Version No. 1.1

Measure Overview

Description: This measure includes replacement of failed or working furnaces and unit heaters in existing buildings with natural gas fired infrared heaters, as well as installation of infrared heaters in new buildings.
Actions: Replace on Fail, Replace Working, New Construction

Target Market Segments: Commercial, Industrial
Target End Uses: HVAC
Applicable to: Commercial customers with natural gas fired forced air heating systems

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = Pre_Annual_Consumption x (1 - Load_Reduction_Factor)

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years): 15 (Ref. 1)

Unit Participant Incremental Cost: $1,716 (Ref. 2)

Where:

Pre_Annual_Consumption = Btuh_In x Load_Factor x CF x HDD65 x 24 x [1/ (T_indoor - T_design)] / ConversionFactor

Load_Reduction_Factor = (HDD55 / (55°F - T_design)) / (HDD65 / (65°F - T_design))

Btuh_In = the nominal rating of the input capacity of the new infrared heater in Btu/h

Load_Factor = load factor, assumed to be 77% (Ref. 3)

CF = correction factor, assumed to be 70% (Ref. 4)

HDD65 = the heating degree-days of the climate zone with a 65 degree base. See Table 1.

HDD55 = the heating degree-days of the climate zone with a 55 degree base. See Table 1.

T_indoor = the temperature of the indoor conditioned space, assumed to be 65 F

T_design = the equipment design temperature of the climate zone, see Table 1

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: New infrared heater input Btu/h, project location (county).

Example:

A 300 Mbtuh infrared heater is installed to replace a furnace of the same size in an existing commercial building in Climate Zone 1.

Pre_Annual_Consumption = 300,000 x 0.77 x 0.70 x 9,833 x 24 x [1 / (65 - (-22))] / 1,000,000 = 439 Dth

*Unit Dth Savings per Year = 439 * [1 - (6,956 / (55 - (-22))) / (9,833 / (65 - (-22)))] = 88 Dth*

Deemed Input Tables:

Table 1: Heating Degrees Days (HDD) and Heating Design Temperature per zone in Minnesota

Minnesota	Zone 1	Zone 2	Zone 3
	(Northern MN)	(Central MN)	(Southern MN/Twin Cities)
HDD65 (Ref. 5)	9,833	8,512	7,651
HDD55 (Ref. 5)	6,956	5,888	5,233
T_design (Ref. 6)	-22 °F	-16.5 °F	-14.5 °F

Methodology and Assumptions:

The calculation methodology for this measure assumes that the space temperature can be dropped 10°F while maintaining occupant comfort levels.

Notes:

There are currently no existing Minnesota state-wide or federal efficiency standards for infrared heaters.

References:

1. Focus on Energy Evaluation, Business Programs: Measure Life Study, August 25, 2009.

2. Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

3. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that heating systems are 30% oversized on average.

4. The correction factor corrects heating usage as building balance points are below 65F, and setback schedules are common. A typical heating degree day correction factor is 0.7. Assuming a typical building balance point temperature of 55F it was found that for a sampling of Minnesota cities HDD55 = 0.7 x HDD65.

5. National Climate Data Center - National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.

6. *2009 ASHRAE Fundamentals Handbook Table 1A Heating and Wind Design Conditions, Heating DB 99.6%*

Documentation Revision History

Version / Description	Author	Date
1. Original document.	FES	7/30/2012
1.1 Added Industrial to Market Segments, corrected use of Btu/Dth conversion factor in algorithm, changed measure name	JP	2/12/2013

C/I HVAC - Steam Trap

Version No. 7.1

Measure Overview

Description: This measure includes the replacement of leaking steam traps that are part of a HVAC steam distribution system, or an industrial process steam system.

Actions: Replace on Fail
Target Market Segments: Commercial, Industrial
Target End Uses: HVAC, Industrial Process

Applicable to: Commercial customers with natural gas fired low-pressure (≤ 15 psig) steam boilers used for space heating, industrial customers with process steam systems

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = Rate_Loss * h_fg * Loss_Factor * EFLH * CF / Heat_Eff / Conversion_Factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 6 (Ref. 1)

Unit Participant Incremental Cost: Use actual or refer to Table 4 if unavailable

Where:

Rate_Loss = rate of steam loss, determined by steam gage pressure and steam trap orifice diameter, determined using Grashof's Equation: lb/hr = 0.70 x 0.0165 x 3600 x A x p^0.97 (Ref. 2).

A = the area of the steam trap orifice in square inches = $\pi d^2/4$, d = diameter of steam trap orifice in inches

P = system pressure in pounds per square inch absolute (psia), psia = psig (gauge pressure) + 14.7 psi at sea level

h_fg = latent enthalpy of vaporization at specified conditions, from Table 3

Loss_Factor = A factor to account for the percentage of the orifice that is open. Assumed to be 50%

EFLH = equivalent full load heating hours, from Table 2

CF = correction factor, assumed to be 70% (Ref. 3)

Heat_Eff = efficiency of the steam boiler. If unknown, use typical value of 80%

Conversion_Factor = 1e-6 MMBtu/Btu

Required from Customer/Contractor: Orifice diameter in inches, steam system pressure in psig, project location (county), trap installed cost OR steam system type (see Table 4)

Optional inputs from customer/contractor: Efficiency of steam boiler

Example:

Replace a leaking 1/8" HVAC steam trap that is part of a 5 psig heating system in Climate Zone 1.

*Rate_Loss = 0.70 * 0.0165 * 3600 * (π*(1/8)^2/4) * (14.7 + 5)^0.97 = 9.2 Btu/hr*

*Dth Savings per Year = 9.2 Btu/hr * 960 * 50% * 2713 * 70% / 80% / 1,000,000 = 10.5 Dth*

Deemed Input Tables:

Table 1: Heating Degrees-Days per zone in Minnesota

Minnesota	Zone 1	Zone 2	Zone 3
HDD (Ref. 4)	9,833	8,512	7,651
Design Temp (Ref. 5)	-22 °F	-16.5 °F	-14.5 °F

Table 2: Equivalent Full Load Hours per zone in Minnesota

Building Description	Zone 1	Zone 2	Zone 3
Heating End-use (Ref. 6)	2,713	2,507	2,310
Production End-use (Ref. 7)	4,567	4,567	4,567

Table 3: Latent Heat of Vaporization for Various Pressures (Ref. 8)

PSIG	Latent Enthalpy of Vaporization (h_fg) (BTU/lb)
2	966
5	960
10	953
15	946
25	934
50	912
75	895
100	880
125	868
150	857
200	837
250	820
300	805

Table 4: Cost Per Steam Trap for Various System Types (Ref. 9)

Steam System Type	Cost per Trap
Commercial Dry Cleaners	$77.00
Commercial Heating , low pressure steam	$77.00
Industrial Medium Pressure >15 psig psig < 30 psig	$180.00
Steam Trap, Industrial Medium Pressure ≥30 <75 psig	$223.00
Steam Trap, Industrial High Pressure ≥75 <125 psig	$276.00
Steam Trap, Industrial High Pressure ≥125 <175 psig	$322.00
Steam Trap, Industrial High Pressure ≥175 <250 psig	$370.00
Steam Trap, Industrial High Pressure ≥250 psig	$418.00
Steam Trap, Industrial Medium Pressure ≥30 <75 psig	$223.00
Steam Trap, Industrial High Pressure ≥75 <125 psig	$276.00
Steam Trap, Industrial High Pressure ≥125 <175 psig	$322.00
Steam Trap, Industrial High Pressure ≥175 <250 psig	$370.00
Steam Trap, Industrial High Pressure ≥250 psig	$418.00

References:

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, October 10, 2008

2. Barney L. Capehart, Wayne C. Turner, William J. Kennedy, "Guide To Energy Management, 6 Ed," The Fairmont Press, Inc., 2008

3. The correction factor corrects heating usage as building balance points are below 65F, and setback schedules are common. A typical heating degree day correction factor is 0.7. Assuming a typical building balance point temperature of 55F if was found that for a sampling of Minnesota cities HDD55 = 0.7 x HDD65.

4. National Climate Data Center - National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.

5. 2009 ASHRAE Fundamentals Handbook Table 1A Heating and Wind Design Conditions, Heating DB 99.6%

6. Calculated using the data in table 1 above, with the equation: EFLH = HDD * 24 / (Inside Temp - Design Temp). Inside Temperature is assumed to be 65°F on average.

7. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010.

8. Keenan, J.H., Keyes, F. G., Hill, P. G., and Moore, J. G. "Steam Tables." John Wiley & Sons, 1969

9. Illinois Statewide Technical Reference Manual-6.4.15 Steam Trap Replacement or Repair,July 18, 2012

Documentation Revision History:

Version / Description	Author	Date
6. Original from Nexant with extraneous tabs hidden	Nexant	
7. Changed measure life and measure life source	FES	7/31/2012
7. Changed incremental cost and cost source	FES	7/31/2012
7. Updated HDD65 and design temperatures based on new 30-year averages.	FES	7/31/2012
7. The references for HDD65, design temperatures, and tune-up savings were changed.	FES	7/31/2012
7. Changed EFLH assumptions and sources	FES	7/31/2012
7. Changed algorithm	FES	7/31/2012
7. Added the variables Oversize_Factor, Conversion_Factor, and Loss_Factor	FES	7/31/2012
7.1 Specified that low pressure is ≤ 15 psig in Applicable To, changed incremental cost to specify that actual may be used, entered required and optional inputs, minor revisions	JP	3/4/2013

Commercial HVAC - Boiler Modifications, Space Heating Only

Version No. 3.5

Measure Overview

Description: This measure describes retrofit opportunities to increase boiler efficiency. This includes cut-out controls, modulating burners, reset controls, oxygen controls, stack dampers, boiler tune-ups, and turbulators. Applies only to natural gas boilers in space heating applications.

Actions: Operations & Maintenance, Modify
Target Market Segments: Commercial, Industrial
Target End Uses: HVAC, Industrial Process
Applicable to: Commercial and industrial customers with HVAC boilers

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Percent Savings) x (Pre-Annual Consumption)

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years): See Table 2

Unit Participant Incremental Cost: Use actual cost of modification. Table 2 figures may be used for planning estimates.

Where:

Pre-Annual Consumption (Dth/yr) = [BTUH_In x Load_Factor x CF x HDD65 x 24 / (T_indoor - T_design)] / ConversionFactor

BTUH_In = the nominal rating of the input capacity of the boiler in Btu/h

Load_Factor = boiler load factor, assumed to be 77% (Ref. 1)

CF = correction factor, assumed to be 70% (Ref. 2)

HDD65 = the heating degree-days of the climate zone with a 65 degree base. See Table 1.

T_indoor = the temperature of the indoor conditioned space in °F, assumed to be 65 °F

T_design = the equipment design temperature of the climate zone. See Table 1.

ConversionFactor = 1,000,000 Btu/Dth

Percent Savings = percent of the pre-modification annual consumption saved. See Table 2.

Required from Customer/Contractor: Modification type, nominal pre-modification Btu/h input, project location (county).

Example:

For a 1000 kBtuh boiler tune-up in Zone 2:

Pre-Annual Consumption (Dth/yr) = [0.77 x 0.70 x 1,000,000 x 8,512 x 24 / (65 - (-16.5))] / 1,000,000) = 1351 Dth

Gas Energy Heating Savings (Dth/yr) = 0.016 x 1,351 = 22 Dth

Deemed Input Tables:

Table 1: Heating Degrees-Days and Design Temperatures by Zone

	Zone 1	Zone 2	Zone 3
	Northern MN	Central MN	Southern MN/Twin Cities
HDD65 (Ref. 3)	9,833	8,512	7,651
Heating design temperature (°F) (Ref. 4)	-22 °F	-16.5 °F	-14.5 °F

Table 2: Modification Savings and Incremental Costs

Modification Type	Percent Savings	Approximate Cost	Measure Life
Cut-out Control	1.7% (Ref. 5)	$141 per boiler (Ref. 5)	5 years (Ref. 10)
Fully Modulating Burner	3% (Ref. 6)	$2.53 per kBtu/h input (Ref. 7)	15 years (Ref. 7)
Outdoor Reset Control	3.8% (Ref. 5)	$600 per boiler (Ref. 5)	5 years (Ref. 10)
Oxygen Control	2% (Ref. 8)	$27,000 per boiler (Ref. 9)	5 years (Ref. 10)
Stack Damper	5% (Ref. 8)	$3.125 per nominal pre-modification kBtu/h input (Ref. 5)	5 years (Ref. 10)
Tune-up	1.6% (Ref. 11)	$0.83/kBtu/h input (Ref. 12)	2 years (Ref. 13)
Turbulators	3% (Ref. 14)	$1,375 per boiler (Ref. 5)	20 years (Ref. 5)

Notes:

There are currently no existing Minnesota state-wide or federal efficiency standards for aftermarket boiler retrofit measures.

References:

1. PA Consulting, KEMA, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that boilers are 30% oversized on average.

2. The correction factor corrects heating usage as building balance points are below 65F, and setback schedules are common. A typical heating degree day correction factor is 0.7. Assuming a typical building balance point temperature of 55F it was found that for a sampling of Minnesota cities HDD55 = 0.7 x HDD65.

3. National Climate Data Center - National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.

4. 2009 ASHRAE Fundamentals Handbook Table 1A Heating and Wind Design Conditions, Heating DB 99.6%

5. CenterPoint Energy, Triennial CIP/DSM Plan 2010-2012, June 1, 2009

6. Xcel Energy, 2010/2011/2012 Triennial Plan, Minnesota Electric and Natural Gas Conservation Improvement Program, E,G002/CIP-09-198

7. Franklin Energy Services review of PY2/PY3 costs for custom People's and Northshore high turndown burner projects, used in Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 3.0, February 14, 2014.

8. United States EPA, Climate Wise: Wise Rules for Industrial Efficiency, July 1998

9. California Utilities Statewide Codes and Standards Team, CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE): PROCESS BOILERS, October 2011

10. Focus on Energy Evaluation, Business Programs: Measure Life Study, August 25, 2009.

11. PA Consulting, KEMA, Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0, March 22, 2010

12. Illinois Statewide Technical Reference Manual, Sections 6.4.3 and 6.4.4, July 18, 2012. This source used data from a work paper provided by Resource Solutions Group that is not available publicly.

13. How to Select, Prioritize, & Justify Economically Viable Energy Projects, Eileen Westervelt, U of I Business Innovation Services, 10-30-2012

14. United States DOE, Industrial Technologies Program, Steam Fact Sheet #25, January 2012

Documentation Revision History:

Version / Description	Author	Date
1. Replaces BoilerCutOutControl_v02, BoilerOutdoorAirReset_v02, BoilerTuneup_v03, ModulatingBurners_v02, O2Control_v02, StackDampers_v01. Changed formulas for consistency (Savings = Pre-Ann Consumption x Percent Savings)	JP	
2. Corrected measure life's	JP	
3. Added the algorithm for PreAnnualConsumption to the algorithms section and removed it from the variables.	FES	7/30/2012

3. Changed algorithm for PreAnnualConsumption from "BTUH_In x HDD x 24 / (T_indoor - T_design) / 1,000,000" to "BTUH_In x BOF x CF x HDD65 x 24 / [(T_indoor - T_design) x ConversionFactor]"	FES	7/30/2012
3. Added the following variables to calculate PreAnnualConsumption: BOF, CF, ConversionFactor	FES	7/30/2012
3. Updated HDD65 and design temperatures based on new 30-year averages	FES	7/30/2012
3. The savings for boiler tune-ups was modified to 1.6%	FES	7/30/2012
3. The references for HDD65, design temperatures, tune-up savings, and modulating burner savings were changed	FES	7/30/2012
3. References for CF and BOF were added	FES	7/30/2012
3. Added example of savings from a tune-up being performed on a 1000 kBtuh boiler in Zone 2	FES	7/30/2012
3. Changed sources and values of incremental costs for modulating burners, oxygen controls, and tune-ups.	FES	7/30/2012
3. Changed sources and values of measure life for all control measures to five years. This is a more realistic value than the previous 20 year measure life, which is appropriate for boilers but not for retrofit boiler controls.	FES	7/30/2012
3. Changed sources and values of measure life for tune-ups and modulating burners.	FES	7/30/2012
3.1 Changed incremental cost formula to specify to use actual cost of modification, minor edits.	JP	3/5/2013
3.2 Changed Market Segments to Commercial only, changed Applicable to commercial customers only (eliminated industrial customers)	JP	11/6/13
3.3 Added Modify to Action Types	JP	11/24/13
3.4 Removed boiler output capacity from required inputs	JP	3/19/14
3.5 Modified incremental cost for fully modulating burners . The former per burner figure did not work with the Smart Measure design. The new figure is from the Illinois Statewide TRM v3.0 and appears to be midway between Xcel and CenterPoint's figures in their 2013-2015 CIP Triennial Plans ($11,619 per boiler and $450/MMBtu, respectively.) Changed cut-out control and outdoor reset control cost descriptions from "per control" to "per boiler" for clarity and consistency with other modification types. Changed stack damper cost from a per Btuh output to a per Btuh input figure assuming a pre-modification efficiency of 80%.	JP	3/27/14

Commercial HVAC - Boilers, Space Heating Only

Version No. 3.1

Measure Overview

Description: This measure includes replacement of failed or working HVAC boilers in existing commercial buildings with high efficiency steam or hot water boilers, as well as installation of high efficiency steam or hot water boilers in new commercial buildings.

Actions: New Construction, Replace on Fail, Replace Working
Target Market Segments: Commercial
Target End Uses: HVAC
Applicable to: Commercial customers with HVAC boilers

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = BTUH_In x Load_Factor x CF x HDD65 x 24 x [1/ (T_indoor - T_design)] x Eff_Base x (1/Eff_Base - 1/Eff_High) / ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years): 20 (Ref. 1)

Unit Participant Incremental Cost: See Table 2.

Where:

BTUH_In = the nominal rating of the input capacity of the boiler in Btu/h

Load_Factor = boiler load factor, assumed to be 77% (Ref. 1)

CF = correction factor, assumed to be 70% (Ref. 2)

HDD65 = the heating degree-days of the climate zone with a 65 degree base. See Table 1.

T_indoor = the temperature of the indoor conditioned space in °F, assumed to be 65 °F

T_design = the equipment design temperature of the climate zone. See Table 1.

Eff_Base = Efficiency of the baseline boiler. See Table 2.

Eff_High = Efficiency of the new high efficiency boiler at actual operating conditions, as estimated by customer/contractor.

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: New boiler input Btu/h, new boiler efficiency at actual operating conditions, new boiler type (steam, steam except natural draft, hot water), existing boiler type (steam, steam except natural draft, hot water), project location (county).

Example:

A 1,000 kBtuh hot water boiler is replaced with a 1,000 kBtuh 88% efficient hot water boiler in Zone 2:

Unit Dth Savings Per Year = 1,000,000 x 0.77 x 0.7 x 8,512 x 24 x [1 / (65 - (-16.5))] x 0.80 x (1/0.80 - 1/0.88) / 1,000,000 = 123 Dth/yr

Deemed Input Tables

Table 1: Heating Degree Days (HDD) and Heating Design Temperature per climate zone

	Zone 1	Zone 2	Zone 3
	Northern MN	Central MN	Southern MN/ Twin Cities
HDD65 (Ref. 4)	9,833	8,512	7,651
T_design (Ref. 5)	-22 °F	-16.5 °F	-14.5 °F

Table 2: Incremental Costs and Baseline Efficiency (Ref. 6, 7, 8, 10)

High Efficiency Replacement Boiler Type	High Efficiency Boiler Efficiency Range*	Baseline Efficiency*	Incre-mental Cost ($ / kBtuh)
Steam, < 300 kBtu/h	82+% AFUE	75% AFUE	$3.30
Steam except natural draft, 300-2500 kBtu/h	83-85% TE	79% TE	$1.44
Steam, natural draft, 300-2500 kBtu/h	83-85% TE	77% TE	$1.44
Steam except natural draft, > 2500 kBtu/h	83-85% CE	80% CE	$1.02
Steam, natural draft, > 2500 kBtu/h	83-85% CE	80% CE	$1.02
Mid-Efficiency Hot Water, < 300 kBtu/h	84.5-88% AFUE	80% AFUE	$5.88
Mid-Efficiency Hot Water, 300-2500 kBtu/h	85-88% TE	80% TE	$4.97
Mid-Efficiency Hot Water, > 2500 kBtu/h	85-88% CE	82% CE	$2.50
High Efficiency Hot Water, < 300 kBtu/h	≥ 88% AFUE	80% AFUE	$9.14
High Efficiency Hot Water, 300-2500 kBtu/h	≥ 88% TE	80% TE	$9.12
High Efficiency Hot Water, > 2500 kBtu/h	≥ 88% CE	82% CE	$7.25

** AFUE = Annual Fuel Utilization Efficiency, CE = Combustion Efficiency, TE = Thermal Efficiency*

Notes

Incremental material cost should be confirmed with manufacturer and project data.

There are currently federal efficiency standards in place for HVAC boiler systems. They are as follows:

Table 3: Federal Efficiency Standards for Products Manufactured On or After March 2, 2012 (Ref. 8)

Boiler Type	Size (Btu/hr)	Efficiency Requirement
Gas-fired, hot water	≥300,000 and ≤2,500,000	80% thermal efficiency
Gas-fired, hot water	>2,500,000	82% combustion efficiency
Oil-fired, hot water	≥300,000 and ≤2,500,000	82% thermal efficiency
Oil-fired, hot water	>2,500,000	84% combustion efficiency
Gas-fired except natural draft, steam	≥300,000 and ≤2,500,000	79% thermal efficiency
Gas-fired except natural draft, steam	>2,500,000	79% thermal efficiency
Gas-fired-natural draft, steam	≥300,000 and ≤2,500,000	77% thermal efficiency
Gas-fired-natural draft, steam	>2,500,000	77% thermal efficiency
Oil-fired, steam	≥300,000 and ≤2,500,000	81% thermal efficiency
Oil-fired, steam	>2,500,000	81% thermal efficiency

Table 4: Federal Efficiency Standards for Products Manufactured On or After March 2, 2022 (Ref. 8)

Boiler Type	Size (Btu/hr)	Efficiency Requirement
Gas-fired natural draft, steam	≥300,000 and ≤2,500,000	79% thermal efficiency
Gas-fired natural draft, steam	>2,500,000	79% thermal efficiency

References

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, October 10, 2008
2. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that boilers are 30% oversized on average.
3. The correction factor corrects heating usage as building balance points are below 65F, and setback schedules are common. A typical heating degree day correction factor is 0.7. Assuming a typical building balance point temperature of 55F if was found that for a sampling of Minnesota cities HDD55 = 0.7 x HDD65.
4. National Climate Data Center - National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.
5. 2009 ASHRAE Fundamentals Handbook Table 1A Heating and Wind Design Conditions, Heating DB 99.6%
6. 2008 Database for Energy-Efficient Resources, Revised DEER Measure Cost Summary, June 2, 2008. All incremental cost values assume replacement on failure.
7. Xcel Energy, 2010/2011/2012 Triennial Plan, Minnesota Electric and Natural Gas Conservation Improvement Program, June 1, 2009

8. Title 10, Code of Federal Regulations, Part 431 - Energy Efficiency Program for Certain Commercial and Industrial Equipment, Subpart E - Commercial Packaged Boilers. January 1, 2010.
9. Franklin Energy Services review of boiler manufacturer data and past projects - December, 2012.
10. ASHRAE Standard 90.1-2004 as adopted by MN Commercial Energy Code (MN Rules Ch. 1323)

Documentation Review History

Version / Description	Author	Date
1. New commercial boiler specification replacing low pressure, high pressure, and hot water boiler sheets from Nexant. Changed algorithm to use a 0.77 oversizing factor (implying 30% oversizing) per gas technical workgroup discussions in 2009, and to use defined efficiencies based on boiler type per Xcel's methodology.	JP	
2. Revised to use installed efficiency per contractor/vendor and baseline efficiencies consistent with ASHRAE 90.1-2004, Table 6.8.1F.	JP	
3. Algorithm is now based on boiler input BTUh, instead of output capacity	FES	7/27/2012
3. Changed savings algorithm to: "Btuh_In x OversizeFactor x CF x HDD65 x 24 x [1/ (T_indoor - T_design)] x Eff_Base x (1/Eff_Base - 1/Eff_High) / ConversionFactor".	FES	7/27/2012
3. Source for OversizeFactor has been changed to a more current source.	FES	7/27/2012
3. Correction factor added to the savings algorithm to account for internal heat gain and nighttime setback.	FES	7/27/2012
3. Added ConversionFactor variable to make algorithm more closely match other boiler modification algorithms.	FES	7/27/2012
3. Updated HDD65 and design temperatures based on new 30-year averages.	FES	7/27/2012
3. The references for HDD65, design temperatures, and tune-up savings were changed.	FES	7/27/2012
3. Changed source for measure life to 2008 Database for Energy-Efficient Resources, removed extraneous sources.	FES	7/27/2012
3. Added example of savings from a tune-up being performed on a 1000 kBtuh boiler in Zone 2.	FES	7/27/2012
3. Changed the incremental cost normalizing unit to ($ / kBtuh).	FES	7/27/2012
3. Changed size category row in incremental cost table to input kBtu/h only.	FES	7/27/2012
3. Changed replacement types in incremental cost table. All incremental costs assume replacement on failure.	FES	7/27/2012
3. Updated required inputs from customer/contractor.	FES	7/27/2012
3. Updated measure description.	FES	7/27/2012
3. Added Federal efficiency standards	FES	7/27/2012

3. Added reference #9 and associated default value and update incremental costs	FES	12/28/2012
3.1 Added missing input descriptions to Algorithm, added baseline efficiencies to Table 2, modified example description to make more clear.	JP	1/2/2014

Commercial HVAC - Energy Recovery Ventilator

Version No. 1.3

Measure Overview

Description:

This measure includes replacement of existing unitary equipment or the optional addition of energy recovery on existing unitary equipment.

This measure analyzes the heating savings potential of an energy recovery ventilator on unitary equipment.

This measure is applicable to all gas-fired heated air systems.

Actions: Replace Working, Modify
Target Market Segments: Commercial & Industrial
Target End Uses: HVAC

Applicable to: Commercial & Industrial customers where air unitary equipment has been/could be installed.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = ((1.08 x CFM)/η x HDD65 x Hours) / 1,000,000 x ERV_E

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years (ref 1)

Unit Participant Incremental Cost = See Table 1 (ref 2)

Where:

CFM = Outside Air flow in cubic feet per minute

ERV_E = Energy Efficiency of ERV. Provided by manufacturer/customer *. If values are not provided use default values in Table 2. (ref. 3)

Hours = Hours of operation per day. Provided by customer.

HDD65 = Heating Degree Days See Table 1. (ref 3)

η = Efficiency of heating equipment. Assume 0.8 (ref 6) unless different efficiency is provided by customer.

1.08 = Conversion factor for flow rate and specific volume of air

1,000,000 = Conversion factor for BTU to Dth

*If heat recovery control strategy uses full air flow by-pass for operation at temperatures causing freezing of condensate, multiply efficiency by 0.75 if not adjusted by manufacturer or customer.

Required from Customer/Contractor: ERV type, outside air cfm, building hours of operation, project location (county)

Example:

Install a heat recovery wheel on a low rise office building in Climate Zone 3. The outside air existing supply rate is 1500 cfm, and the building is open on average 12 hours per day.

Unit Dth Savings per Year = ((1.08 x 1500) / 0.8 x 7651 x 12) / 1,000,000 x 0.68 = 126 Dth

Deemed Input Tables:

Table 1: Heating design temperature and heating degree days.

Zone #	HDD65
Northern: #1	9883
Central: #2	8512
Southern: #3	7651

Table 2: Energy Recovery Heating Efficiencies and Incremental Cost

Energy Recover Type	Heating Eff. (ref.7)	Incremental Cost** / CFM (ref. 2)
Fixed Plate*	0.65	$6
Rotary Wheel	0.68	$6
Heat Pipe	0.55	$6

*If heat recovery control strategy uses full air flow by-pass for operation at temperatures causing freezing of condensate, multiply efficiency by 0.75 if not adjusted by manufacturer or customer.

*** Cost includes cabinet and controls incorporated into packaged and built up air handler units.*

Methodology and Assumptions:

Default efficiencies assume 1 to 1 ratio of fresh vs. exhaust/relief air.

Savings due not include any savings from reduced energy for humidification.

Studies have shown that the cooling savings have been offset by the increased fan energy in all areas of MN.

Gas savings algorithm is derived from the following:

Energy = Design Heating Load / Eff. x Equivalent full load hours x conversion

Where: Design Heating Load = (1.08 x CFM x ΔT), Equivalent full load hours = HDD65 x 24 / ΔT x Hours/24 ,

ΔT = Difference in temperature (°F) between the return air conditions (ref. 5) and the design day outside air conditions

Unit Dth Savings per Year = ((1.08 x CFM x ΔT)/η x HDD65 x Hours /ΔT / 1,000,000 x SF_H

Unit Dth Savings per Year = ((1.08 x CFM)/η x HDD65 x Hours) / 1,000,000 x SF_H

Notes:

IECC 2012 will include new ERV requirements at significantly lower outside air flow due to the cost/benefit studies performed by the ASHRAE 90.1-2010 mechanical sub-committee. In addition, the "green code" ASHRAE Standard 189 further reduces outdoor air thresholds requiring ERV and increases minimum ERV effectiveness to 60%.

Code requires Energy Recovery Ventilation for certain applications where the OA exceeds 70% of the 5000 or more CFM supply air of a unit.

References:

1. Assumed service life limited by controls -" Demand Control Ventilation Using CO2 Sensors", pg. 19, by US Department of Energy Efficiency and Renewable Energy

2. "Map to HVAC Solutions", by Michigan Air, Issue 3, 2006

3/ National Climate Data Center - National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.

4. 2009 ASHRAE Handbook HVAC Fundamentals

5. Assumed heating set point of 70°F, FES

6. Assumed standard combustion efficiency of heating equipment, FES

7. Energy Recovery Fact Sheet - Center Point Energy, MN

Documentation Revision History:

Version	Description	Author	Date
1	New savings specification for retrofit/incorporation of energy recovery ventilators.	FES	8/1/2012

1.1	Corrected algorithm and removed delta-T's which cancel, removed design temp and indoor setpoint from Table 1, revised description to make more clear, changed fixed plate footnote under Table 2 from "reduce efficiency by 75%" to "multiply efficiency by 0.75" to be clear, changed Heat. Eff. reference in Table 2 to 7, added content to Methodology & Assumptions showing derivation of gas savings algorithm, changed example to remove delta-T's	JP	3/15/2013
1.2	Corrected zone label for Mpls/St. Paul in Table 1, corrected savings algorithm to use ERV_E instead of SF_H, corrected example	JP	3/27/2013
1.3	Added Modify to action types	JP	11/24/13

Commercial HVAC - Exhaust Energy Recovery

Version No. 1.4

Measure Overview

Description:

This measure includes the addition of energy recovery on new and existing exhaust systems.

This measure analyzes the heating savings potential of the heat energy recovery from exhausted air.

This measure is applicable to HVAC and process exhaust air systems above 200° F where a single point of exhaust is less than 75% of outside air flow rate.

Actions: Replace Working, New Construction, Modify

Target Market Segments: Commercial & Industrial
Target End Uses: HVAC

Applicable to: Commercial & Industrial customers where energy can be recovered from exhausted air.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = 4.5 x CFM x Δh x Hours x HDD_65 x ERV_E / (1,000,000 x ΔT x η)

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years (ref 1)

Unit Participant Incremental Cost = See Table 1 (ref 2)

Where:

CFM = Exhaust Air flow in cubic feet per minute

ERV_E = Energy Efficiency of ERV. Provided by manufacturer/customer *. If values are not provided use default values in Table 2. (ref. 3)

Hours = Hours of operation per day. Provided by customer.

ΔT = Difference in temperature (°F) between the exhaust air heat exchanger inlet and design day heating dry bulb temperature. See Table 1 for default values if not provided.

η = Efficiency of heating equipment of media gaining energy. Assume 0.8 (ref 6) unless different efficiency is provided by customer.

4.5 = Conversion factor for flow rate and specific volume of air and minutes to hours

HDD_65 = Heating Degree Days in a year with a base of 65°F. See Table 1 for default values.

Δh = Difference in enthalpies (btu/lb) between the exhaust air heat exchanger inlet and design day heating dry bulb temperature. See Table 1 for default values if not provided.

1,000,000 = Conversion factor for BTU to Dth

*If heat recovery control strategy uses full air flow by-pass for operation at temperatures causing freezing of condensate, multiply efficiency by 0.75 if not adjusted by manufacturer or customer (Ref. 8.)

Required from Customer/Contractor: Air to air heat exchanger type (fixed plate or runaround loop), exhaust air CFM, hours per day of building operation, project location (county)

Example:

Install a plate heat exchanger on centralized bathroom exhaust on apartment building in Climate Zone 2. The exhaust air existing rate is 500 cfm, and the building is open on average of 24 hours per day.

The plate heat exchanger will be bypassed at temperatures below 35°F to prevent freezing of condensate in exchanger.

Unit Dth Savings per Year = 4.5 x 500 x (25.34 – (-3.79) x 24 x 8512 x 0.65 x 0.75 / (1,000,000 x (70 – (-16.5)) x 0.8) = 94 Dth

Deemed Input Tables:

Table 1: Enthalpies, temperatures and HHD65.

Zone #	Design Temp. Heating (°F) (ref. 4)	Design Temp. Enthalpy (Btu/lb) (ref. 7)	Heating Return Temp. (°F) (ref. 5)	Heating Return Enthalpy (Btu/lb) (ref. 7)	HDD65 (ref. 3)
Northern: #1	-22.0	-4.66	70.00	25.34	9833
Central: #2	-16.5	-3.79	70.00	25.34	8512
Southern /Twin Cities: #3	-14.5	-3.29	70.00	25.34	7651

Table 2: Air Heat Exchanger Efficiencies and Incremental Costs

Energy Recovery Type	Heating Eff. (ref. 3)	Incremental Cost (ref. 2)
Fixed Plate*	0.65	$3/CFM
Runaround Loop*	0.60	$3/CFM

*If heat recovery control strategy uses full air flow bypass for operation at temperatures causing freezing of condensate, multiply efficiency by 0.75 if not adjusted by manufacturer or customer (Ref. 8.)

Methodology and Assumptions:

Runaround loop costs assume no special coatings and relatively short distance between coils.

Notes:

Enthalpies were calculated assuming a relative humidity of 50%.

References:

1. Assumed service life limited by controls -" Demand Control Ventilation Using CO2 Sensors", pg. 19, by US Department of Energy Efficiency and Renewable Energy

2. "Map to HVAC Solutions", by Michigan Air, Issue 3, 2006

3. Energy Recovery Fact Sheet - Center Point Energy, MN

3. National Climate Data Center - National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.

4. 2009 ASHRAE Handbook HVAC Fundamentals

5. Assumed heating set point of 70°F, FES

6. Assumed standard combustion efficiency of heating equipment, FES

7. Values calculated using Trane HDPsyChart Professional Edition, Version 3.1.61.

8. FES engineering estimate

Documentation Revision History:

Version	Description	Author	Date
1	New savings specification for retrofit/incorporation of energy recovery.	FES	8/1/2012
1.1	Changed Table 2 footnote from "reduce efficiency by 75%" to "multiply efficiency by 0.75" to be clear, changed action to replace working, fixed example calculation, changed description from "applicable to all exhaust air systems" to "applicable to HVAC and kitchen hood exhaust air systems", changed days to year from 365 to 365.25 for consistency with other measures	JP	3/13/2013
1.2	Added New Construction and Modify to Action Types	JP	11/24/13
1.3	Modified equation to be HDD based, instead of temperature based to reflect savings for heating season only. Change exhaust air temperature reference to typical building occupied set point. Changed conversion factor from 1.08 to 4.5 to correct change in equation base. Added heating degree days and enthalpies definitions. Update example. Modified Table 2 to include return air temperature, enthalpies and HHD values. Changed notes. Added references.	Franklin Energy Services	7/18/2014
1.4	Corrected example and typos, added reference for efficiency derating factor.	JP	8/1/2014

Commercial HVAC - Forced-Air Heating Maintenance

Version No. 1.1

Measure Overview

Description: This measure includes the maintenance of forced-air space heating systems in commercial spaces. This includes furnaces, RTUs, unit heaters, and makeup air units, for example. This does not include boiler or infrared heater maintenance.

*Applies to heating equipment in space heating applications only.

Actions: Operations & Maintenance
Target Market Segments: Commercial
Target End Uses: HVAC

Applicable to: Commercial customers with natural gas fired, forced-air heating systems

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Percent Savings) x (Pre-Annual Consumption)

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years): 3 (Ref. 1)

Unit Participant Incremental Cost: $0.83/MBtuh (Ref. 2)

Where:

Pre-Annual Consumption (Dth/yr) = BTUH_In x Load_Factor x CF x HDD65 x 24 / [(T_indoor - T_design) x ConversionFactor]

Percent Savings = percent of the pre-modification annual consumption saved. Assumed to be 1.6% on average. (Ref. 5)

BTUH_In = the nominal rating of the input capacity of the heating equipment in Btu/h

Load_Factor = oversizing factor, assumed to be 77% (Ref. 3)

CF = correction factor, assumed to be 70% (Ref. 4)

HDD65 = the heating degree-days of the climate zone with a 65 degree base. See Table 1.

T_indoor = the temperature of the indoor conditioned space in °F, assumed to be 65 °F

T_design = the equipment design temperature of the climate zone. See Table 1.

ConversionFactor = 1e-6 Dth/Btu

Required from Customer/Contractor: Nominal Btu/h input of heating system, project location (county)

Example:

For maintenance performed on a 150 MBtuh heating unit in Zone 2:

Pre-Annual Consumption (Dth/yr) = 150,000 x 0.77 x 0.70 x 8,512 x 24 / [(65 - (-16.5)) x 1,000,000)] = 1001 Dth

Gas Energy Heating Savings (Dth/yr) = 0.016 x 1,001 = 16 Dth

Deemed Input Tables:

Table 1: Heating Degrees-Days and Design Temperatures by Zone

	Zone 1	Zone 2	Zone 3
	Northern MN	Central MN	Southern MN/Twin Cities
HDD65 (Ref. 6)	9,833	8,512	7,651
Heating design temperature (°F) (Ref. 7)	-22 °F	-16.5 °F	-14.5 °F

Notes:

There are currently no existing Minnesota state-wide or federal efficiency standards for heating maintenance.

References:

1. Typical measure life's assumed for heating maintenance and tune-ups range from 1 to 5 years, see: "Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up," for example, at 3 years.

2. Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

3. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that heating systems are 30% oversized on average.

4. The correction factor corrects heating usage as building balance points are below 65F, and setback schedules are common. A typical heating degree day correction factor is 0.7. Assuming a typical building balance point temperature of 55F if was found that for a sampling of Minnesota cities HDD55 = 0.7 x HDD65.

5. Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0, March 22, 2010. Assuming the same savings percentage value as Boiler Tune-Ups.

6. National Climate Data Center - National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.

7. 2009 ASHRAE Fundamentals Handbook Table 1A Heating and Wind Design Conditions, Heating DB 99.6%

Documentation Revision History:

Version / Description	Author	Date
1. Original document.	FES	7/30/2012
1.1 Changed name	JP	2/11/2013

Commercial Food Service – ENERGY STAR Gas Combination Oven

Version No. 1.3

Measure Overview

Description:

This measure includes the replacement of a gas combination oven with an ENERGY STAR gas combination oven, or installation of an ENERGY STAR combination oven in new construction.

ENERGY STAR combination ovens incorporate timesaving features via sophisticated control packages.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Eday_base - Eday_prop) / Conversion Factor x Day

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $5,717 (Ref. 2)

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (Btu/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

LBFood = 200 lbs/day; Pounds of food cooked per day (Ref. 2)

Efood = 250 Btu/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 35%; Heavy load cooking energy efficiency (Ref. 6)

Eff_prop = 48.5% (Ref. 6)

IdleRate_base = 28,000 Btu/hr; Idle Energy Rate (Ref. 2)

IdleRate_prop = 14,000 Btu/hr (Ref. 7)

OpHrs = 8 hrs/day; Daily operating hours (Ref. 5)

PC_base = 80 lbs/hr; Production Capacity (Ref. 2)

PC_prop = 120 lbs/hr (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 18,000 Btu/day; Preheat energy (Ref. 2)

E_pre_prop = 13,000 Btu/day (Ref. 2)

Days = See Table 1

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: building type

Example:

A hospital cafeteria installed a new ENERGY STAR gas combination oven.

Eday_base (Btu/day) = (200 lbs/day) x (250 Btu/lb) / (35%) + [28,000 Btu/hr x (8 hrs/day - (200 lbs/day / 80 lb/hr) - (15 min / 60 min/hr))] + 18,000 Btu/day = 307,857 Btu/day

Eday_prop (Btu/day) = (200 lbs/day) x (250 Btu/lb) / (48.5%) + [14,000 Btu/hr x (8 hrs/day - (200 lbs/day / 120 lb/hr) - (15 min / 60 min/hr))] + 13,000 Btu/day = 201,259 Btu/day

Unit Dth Savings per Year = (307,857 Btu/day - 201,259 Btu/day) / 1,000,000 Btu/Dth x 365.25 days/yr = 38.9 Dth

Deemed Input Tables:

Table 1: Operation Hours by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
Other Commercial	250

Methodology and Assumptions:

Table 2: ENERGY STAR Gas Combination Oven Criteria (Ref. 6, 7)

Operation	Idle Rate, Btu/h	Cooking-Energy Efficiency, %
Steam Mode	≤ 200P+6,511	≥ 41
Convection Mode	≤ 150P+5,425	≥ 56
Average (assuming 6-pan unit)	**14,000**	**48.5**

Notes:

There is no code requirement for this technology.

References:

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

2. *Commercial Combination Ovens,* Food Service Equipment Workpaper PGECOFST100 R1, PG&E. June 1, 2009.

3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

4. *2008 Database for Energy-Efficient Resources Version 2008.2.05 December 16, 2008; www.deeresources.com / DEER 2005 / DEER 2005 Version Reports and Notifications/ DEER 2005 Version 2.01 Enhancements and Notifications*

5. *Technology Assessment: Ovens,* Food Service Technology Center, 2002. Page 7-22. http://www.fishnick.com/equipment/techassessment/7_ovens.pdf

6. Average of steam and convection cooking efficiencies listed in ENERGY STAR Commercial Ovens Key Product Criteria, Version 2.1. http://www.energystar.gov/index.cfm?c=ovens.pr_crit_comm_ovens. Accessed 7/9/14.

7. Sum of steam and convection oven idle rates (summed because they can be used simultaneously), assuming 6-pans to be conservative, rounded to nearest tenth. Ref. 5.

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/27/2012
1.1 Renamed measure	JP	2/8/2013
1.2 Updated to include ENERGY STAR version 2.1 specification	Franklin Energy Services	7/31/2014
1.3 Updated description to include new construction, changed 365 to 365.25 for consistency with other measures, put Table 2 in Methodology & Assumptions section	JP	7/31/2014

Commercial Food Service – ENERGY STAR Gas Convection Oven

Version No. 1.1

Measure Overview

Description:

This measure includes installation of high efficiency ENERGY STAR gas convection ovens instead of standard efficiency units.

Energy efficient commercial gas ovens reduce energy consumption primarily through sophisticated control packages.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Eday_base - Eday_prop) / Conversion Factor x Days

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $1,886 (Ref. 2)

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (Btu/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

LBFood = 100 lbs/day; Pounds of food cooked per day (Ref. 2)

Efood = 250 Btu/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 30%; Heavy load cooking energy efficiency (Ref. 2)

Eff_prop = 44% (Ref. 4)

IdleRate_base = 18,000 Btu/hr; Idle Energy Rate (Ref. 2)

IdleRate_prop = 13,000 Btu/hr (Ref. 4)

OpHrs = 8 hrs/day; Daily operating hours (Ref. 5)

PC_base = 70 lbs/hr; Production Capacity (Ref. 2)

PC_prop = 80 lbs/hr (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 19,000 Btu/day; Preheat energy (Ref. 2)

E_pre_prop = 11,000 Btu/day (Ref. 2)

Days = See Table 1

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: building type

Example:

A sit-down restaurant installed a new ENERGY STAR Gas Convection Oven

Eday_base (Btu/day) = (100 lbs/day) x (250 Btu/lb) / (30%) + [18,000 Btu/hr x (8 hrs/day - (100 lbs/day / 70 lb/hr) - (15 min / 60 min/hr))] + 19,000 Btu/day = 216,119 Btu/day

Eday_prop (Btu/day) = (100 lbs/day) x (250 Btu/lb) / (44%) + [13,000 Btu/hr x (8 hrs/day - (100 lbs/day / 80 lb/hr) - (15 min / 60 min/hr))] + 11,000 Btu/day = 152,318 Btu/day

Unit Dth Savings per Year = (216,119 Btu/day - 152,318 Btu/day) / 1,000,000 Btu/Dth x 365 days/yr = 23.3 Dth

Deemed Input Tables:

Table 1: Operation Hours by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Notes:

There is no code requirement for this technology.

ENERGY STAR requires that Full Size Gas Ovens have a cooking energy efficiency ≥ 44% and an idle energy rate ≤ 13,000 Btu/h (Ref. 4)

References:

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

2. Commercial Convection Ovens, Food Service Equipment Workpaper PGEOFST101 R1, PG&E. June 1, 2009.

3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

4. Commercial Ovens Key Product Criteria, http://www.energystar.gov/index.cfm?c=ovens.pr_crit_comm_ovens. Accessed August, 15, 2012.

5. Technology Assessment: Ovens, Food Service Technology Center, 2002. Page 7-22. http://www.fishnick.com/equipment/techassessment/7_ovens.pdf

Documentation Revision History

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/14/2012
1.1 Renamed measure	JP	2/8/2013

Commercial Food Service – ENERGY STAR Gas Fryer

Version No. 1.1

Measure Overview

Description: This measure includes installation of high efficiency ENERGY STAR gas fryers instead of standard efficiency units. Energy efficient commercial gas fryers reduce energy consumption primarily through advanced burner and heat exchanger design and the application of advanced controls and insulation.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Eday_base - Eday_prop) / Conversion Factor x Days

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $1,219 (Ref. 2)

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (Btu/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

LBFood = 150 lbs/day; Pounds of food cooked per day (Ref. 2)

Efood = 570 Btu/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 35%; Heavy load cooking energy efficiency (Ref. 2)

Eff_prop = 50% (Ref. 2)

IdleRate_base = 14,000 Btu/hr; Idle Energy Rate (Ref. 2)

IdleRate_prop = 9,000 Btu/hr (Ref. 2)

OpHrs = 12 hrs/day; Daily operating hours (Ref. 5)

PC_base = 60 lbs/hr; Production Capacity (Ref. 2)

PC_prop = 65 lbs/hr (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 16,000 Btu/day; Preheat energy (Ref. 2)

E_pre_prop = 15,500 Btu/day (Ref. 2)

Days = See Table 1

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: building type

Example:

A grocery store installed a new ENERGY STAR Gas Fryer

Eday_base (Btu/day) = (150 lbs/day) x (570 Btu/lb) / (35%) + [14,000 Btu/hr x (12 hr/day - (150 lbs/day / 60 lb/hr) - (15 min / 60 min/hr))] + 16,000 Btu/day = 389,785 Btu/day

Eday_prop (Btu/day) = (150 lbs/day) x (570 Btu/lb) / (50%) + [9,000 Btu/hr x (12 hr/day - (150 lbs/day / 65 lb/hr) - (15 min / 60 min/hr))] + 15,500 Btu/day = 271,481 Btu/day

Unit Dth Savings per Year = (389,785 Btu/day - 271,481 Btu/day) / 1,000,000 Btu/Dth x 365 days/yr = 43.2 Dth

Deemed Input Tables:

Table 1: Operation Hours by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Notes:

There is no code requirement for this technology.

ENERGY STAR requires Standard Open Deep-Fat Gas Fryers have a heavy-load cooking efficiency ≥ 50% and an idle energy rate ≤ 9,000 Btu/h (Ref. 4)

ENERGY STAR requires Large Vat Open Deep-Fat Gas Fryers have a heavy-load cooking efficiency ≥ 50% and an idle energy rate ≤ 12,000 Btu/h (Ref. 4)

References:

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

2. *Commercial Fryer,* Food Service Equipment Workpaper PGEOFST102 R1, PG&E. June 1, 2009.

3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

4. *Commercial Fryers Key Product Criteria,* http://www.energystar.gov/index.cfm?c=fryers.pr_crit_fryers. Accessed August, 15, 2012.

5. *Technology Assessment: Fryer,* Food Service Technology Center, 2002. Page 2-20. http://www.fishnick.com/equipment/techassessment/2_fryers.pdf

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/14/2012
1.1 Changed measure name	JP	2/8/2013

Commercial Food Service – ENERGY STAR Gas Griddle

Version No. 1.1

Measure Overview

Description: This measure includes installation of high efficiency ENERGY STAR gas griddles instead of standard efficiency units. Energy efficient commercial gas griddles reduce energy consumption primarily through advanced burner design and controls.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Eday_base - Eday_prop) / Conversion Factor x Days

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $1,912 (Ref. 6)

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (Btu/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

LBFood = 100 lbs/day; Pounds of food cooked per day (Ref. 2)

Efood = 475 Btu/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 32%; Heavy load cooking energy efficiency (Ref. 2)

Eff_prop = 38% (Ref. 4)

IdleRate_base = 19,000 Btu/hr; Idle Energy Rate (Ref. 2)

IdleRate_prop = 16,000 Btu/hr (Ref. 2)

OpHrs = 12 hrs/day; Daily operating hours (Ref. 5)

PC_base = 25 lbs/hr; Production Capacity (Ref. 2)

PC_prop = 45 lbs/hr (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 21,000 Btu/day; Preheat energy (Ref. 2)

E_pre_heat = 15,000 Btu/day (Ref. 2)

Days = See Table 1

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: building type

Example:

A sit-down restaurant installed a new ENERGY STAR Gas Griddle

Eday_base (Btu/day) = (100 lbs/day) x (475 Btu/lb) / (32%) + [19,000 Btu/hr x (12 hr/day - (100 lbs/day / 25 lb/hr) - (15 min / 60 min/hr))] + 21,000 Btu/day = 316,688 Btu/day

Eday_base (Btu/day) = (100 lbs/day) x (475 Btu/lb) / (38%) + [16,000 Btu/hr x (12 hr/day - (100 lbs/day / 45 lb/hr) - (15 min / 60 min/hr))] + 15,000 Btu/day = 292,444 Btu/day

Unit Dth Savings per Year = (316,688 Btu/day - 292,444 Btu/day) / 1,000,000 Btu/Dth x 365 days/yr = 8.8 Dth

Deemed Input Tables:

Table 1: Operation Hours by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Methodology and Assumptions:

Savings assumes a 3' x 2' griddle size and a Tier 1 idle rate.

Notes:

There is no code requirement for this technology.

ENERGY STAR requires that Gas Griddles have a cooking energy efficiency ≥ 38% and a normalized idle energy rate ≤ 2,650 Btu/h per ft^2 (Ref. 4).

References:

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

2. *Commercial Griddles,* Food Service Equipment Workpaper PGECOFST103 R1, PG&E. June 1, 2009.

3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

4. *Commercial Griddles Key Product Criteria,* http://www.energystar.gov/index.cfm?c=griddles.pr_crit_comm_griddles. Accessed August, 15, 2012.

5. *Technology Assessment: Griddles,* Food Service Technology Center, 2002. Page 3-22. http://www.fishnick.com/equipment/techassessment/3_griddles.pdf

6. *Based on Vulcan-Hart pricing from KaTom.com, see Costs tab.*

Documentation Revision History

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/14/2012
1.1 Renamed measure	JP	2/8/2013

Commercial Food Service – ENERGY STAR Gas Steamer

Version No. 1.0

Measure Overview

Description: This measure includes replacement of commercial gas steamers with new 5 or 6-pan ENERGY STAR gas steamers.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Eday_base - Eday_prop) / Conversion Factor x Days

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $3,732 (Ref. 2)

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + (IdleRate_base + Res_Rate_base) x (OpHrs - LBFood / PC_base - T_pre / 60) + E_pre_base

Eday_prop (Btu/day) = LBFood x Efood / Eff_prop + (IdleRate_prop + Res_Rate_prop) x (OpHrs - LBFood / PC_prop - T_pre / 60) + E_pre_prop

LBFood = See Table 1; Pounds of food cooked per day (Ref. 2)

Efood = 105 Btu/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 15%; Heavy load cooking energy efficiency (Ref. 2)

Eff_prop = 38% (Ref. 2)

IdleRate_base = See Table 1; Idle Energy Rate (Ref. 2)

IdleRate_prop = See Table 1 (Ref. 2)

OpHrs = 12 hrs/day; Daily operating hours (Ref. 2)

PC_base = See Table 1; Production Capacity (Ref. 2)

PC_prop = See Table 1 (Ref. 2)

Res_Rate_base = 45,080 Btu/h; Residual Energy Rate (Ref. 2)

Res_Rate_prop = 1,658 Btu/h; Residual Energy Rate (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 18,000 Btu/day; Preheat energy (Ref. 2)

E_pre_prop = 9,000 Btu/day (Ref. 2)

Days = See Table 2

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: building type, number of pans (5 or 6)

Example:

A fast-food restaurant installed a new 5-pan ENERGY STAR Gas Steamer

Eday_base (Btu/day) = (100 lbs/day) x (105 Btu/lb) / (15%) + (16,000 Btu/hr + 45,080 Btu/h) x (12 hrs/day - (100 lbs/day / 140 lb/hr) - (15 min / 60 min/hr)) + 18,000 Btu/day = 762,061 Btu/day

Eday_prop (Btu/day) = (100 lbs/day) x (105 Btu/lb) / (38%) + (12,500 Btu/hr + 1,658 Btu/h) x (12 hrs/day - (100 lbs/day / 120 lb/hr) - (15 min / 60 min/hr)) + 9,000 Btu/day = 191,190 Btu/day

Unit Dth Savings per Year = (762,061 Btu/day - 191,190 Btu/day) / 1,000,000 Btu/Dth x 365 days/yr = 208.4 Dth

Deemed Input Tables:

Table 1: Steamer Characteristics

	5-Pan Steamer	6-Pan Steamer
LBFood (lbs/day)	83	100
Efood (Btu/lb)	105	105
Eff_base (%)	15%	15%
Eff_prop (%)	38%	38%
IdleRate_base (Btu/hr)	13,333	16,000
IdleRate_prop (Btu/hr)	10,400	12,500
OpHrs (hrs/day)	12	12
PC_base (lbs/hr)	117	140
PC_prop (lbs/hr)	100	120
Res_Rate_base (Btu/h)	45,080	45,080
Res_Rate_prop (Btu/h)	1,658	1,658
T_pre (minutes)	15	15
E_pre_base (Btu)	18,000	18,000
E_pre_prop (Btu)	9,000	9,000

Table 2: Operation Hours by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Notes:

There is no code requirement for this technology.

ENERGY STAR requires that Gas Steam Cookers have the following efficiencies (Ref. 4):

Pan Capacity	Cooking Energy Efficiency	Idle Rate (Btu/h)
3-Pan	38%	6,250
4-Pan	38%	8,350
5-Pan	38%	10,400
6-Pan	38%	12,500

References:

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

2. *Commercial Steam Cookers,* Food Service Equipment Workpaper PGECOFST104 R1, PG&E. June 1, 2009.

3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

4. *Commercial Steam Cookers Key Product Criteria,* http://www.energystar.gov/index.cfm?c=steamcookers.pr_crit_steamcookers. Accessed August, 27, 2012.

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/27/2012

Commercial Food Service - Gas Conveyor Oven

Version No. 1.1

Measure Overview

Description: This measure includes the replacement of a standard efficiency gas conveyor oven with a high efficiency model. High-efficiency conveyor ovens can achieve higher efficiencies through use of independently controlled temperature zones and air curtains at the ends of the oven.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Eday_base - Eday_prop) / Conversion Factor x Days

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $1,751 for small; $4,731 for large (Ref. 2)

Where:

Eday_base (Btu/day)= nPizza x Efood / Eff_base + IdleRate_base x [OpHrs - nPizza / PC_base - T_pre / 60] + E_pre_base

Eday_prop (Btu/day) = nPizza x Efood / Eff_prop + IdleRate_prop x [OpHrs - nPizza / PC_prop - T_pre / 60] + E_pre_prop

nPizza = See Table 1; Pizzas cooked per day (Ref. 2)

Efood = 190 Btu/pizza; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 20%; Heavy load cooking energy efficiency (Ref. 2)

Eff_prop = 42% (Ref. 2)

IdleRate_base = See Table 1; Idle Energy Rate (Ref. 2)

IdleRate_prop = See Table 1 (Ref. 2)

OpHrs = 10 hrs/day; Daily operating hours (Ref. 4)

PC_base = See Table 1; Production Capacity (Ref. 2)

PC_prop = See Table 1 (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = See Table 1; Preheat energy (Ref. 2)

E_pre_prop = See Table 1 (Ref. 2)

Days = See Table 2

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: building type, width of conveyor (≤ 25"or > 25")

Example:

A fast-food pizzeria installed a new 25-in. high efficiency gas conveyor oven.

Eday_base (Btu/day) = (75 pizzas/day) x (190 Btu/pizza) / (20%) + [45,000 Btu/hr x (10 hrs/day - (75 pizzas/day / 55 pizzas/hr) - (15 min / 60 min/hr))] + 16,000 Btu/day = 464,636 Btu/day

Eday_prop (Btu/day) = (75 pizzas/day) x (190 Btu/pizza) / (42%) + [29,000 Btu/hr x (10 hrs/day - (75 pizzas/day / 75 pizzas/hr) - (15 min / 60 min/hr))] + 8,000 Btu/day = 295,679 Btu/day

Unit Dth Savings per Year = (464,636 Btu/day - 295,679 Btu/day) / 1,000,000 Btu/Dth x 365 days/yr = 61.7 Dth

Deemed Input Tables:

Table 1: Conveyor Characteristics

	Small Conveyor (≤ 25-in. width)	Large Conveyor Oven (> 25-in. width)
nPizza (pizzas/day)	75	150
Efood (Btu/pizza)	250	250
Eff_base (%)	20%	20%
Eff_prop (%)	42%	42%
IdleRate_base (Btu/hr)	45,000	70,000
IdleRate_prop (Btu/hr)	29,000	57,000
OpHrs (hrs/day)	10	10
PC_base (pizzas/hr)	55	150
PC_prop (pizzas/hr)	75	225
T_pre (minutes)	15	15
E_pre_base (Btu)	16,000	35,000
E_pre_prop (Btu)	8,000	18,000

Table 2: Operation Hours by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Notes:

There is no code requirement for this technology.

Small conveyor ovens are defined as having a conveyor width of 25-in. or less

Large conveyor ovens are defined as having a conveyor width of greater than 25-in.

References:

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

2. *Commercial Conveyor Ovens,* Food Service Equipment Workpaper PGECOFST117 R1, PG&E. June 1, 2009.

3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

4. *Technology Assessment: Ovens,* Food Service Technology Center, 2002. Page 7-22. http://www.fishnick.com/equipment/techassessment/7_ovens.pdf

Documentation Revision History:

Version / Description	Author	Date
1) Put together algorithm	Franklin Energy Services	8/27/2012
1.1) Replaced LBFood in algorithms with nPizza, changed measure name	JP	2/8/2013

Commercial Food Service - Gas Oven, Broiler, Pasta Cooker

Version No. 3.1

Measure Overview

Description: This measure includes replacement of failed or working gas food service equipment with new high efficiency food service equipment.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = HVAC_Savings_Factor x BTUH_In / 1,000 kWh/Wh

Unit Peak kW Savings = 0

Unit Dth Savings per Year = BTUH_In x BTU_Savings_Factor / 1,000,000

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 2)

Unit Participant Incremental Cost = See Table 1

Where:

BTUH_In = Nameplate input Btu/h of equipment meeting installation standard (provided by the customer/contractor)

BTU_Savings_Factor = Deemed annual Btu savings per nameplate Btu/h input rating

HVAC_Savings_Factor = Deemed annual electricity savings from HVAC interactive effects (Watt-hours per installed Btu/h input)

Required from Customer/Contractor: Input Btu/h of new equipment, new equipment type

Example:

A fast-food restaurant installed a new high efficiency 48,000 Btu/h Pasta Cooker

*Unit Dth Savings per Year = 48,000 Btu/h x (1,689 Btu/ (Btu/h*yr)) / 1,000,000 Btu/Dth = 81.0 Dth*

Deemed Input Tables:

Table 1: Pre- and Post-retrofit Equipment, Savings Factors, and Incremental Costs

Baseline Equipment	Efficient Equipment	BTU Savings Factor (Btu / ((Btu/h)-yr)) (Ref. 1)	HVAC Savings Factor (Watt-hours / ((Btu/h)-yr) (Ref. 1)	Incremental Cost ($/unit) (Ref. 3)
Open Flame Rotisserie Oven	Efficient Rotisserie Oven	554	15	$2,665
Range	Pasta Cooker	1,689	46	$2,413
Standard Charbroiler	Efficient Charbroiler	1,078	29	$2,173
Standard Radiant Broiler	Efficient Upright Broiler	1,041	30	$4,413
Standard Salamander Broiler	Efficient Salamander Broiler	885	28	$1,006

Notes:

The following technologies have been removed from Table 1 because they now have their own measure:

Convection Oven, Rack Oven, Conveyor Oven, Fryer, Griddle and Combination Oven

References:

1. Savings per installed BTU derived from the Arkansas Food Service Deemed Savings table

2. Measure life for similar food service equipment, 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

3. Incremental costs confirmed using "Commercial Cooking Appliance Technology Assessment, FSTC Report #5011.02.2, Food Service Technology Center, 2002" and product manufacturer Web sites

Documentation Revision History:

Version / Description	Author	Date
1. Original from Nexant with extraneous tabs hidden	Nexant	
2. Cleaned up; removed extraneous fields, clarified that BTUH_In is specified by customer, added incremental costs, corrected HVAC effects formula to convert to kWh, added lifetime	JP	
2.1 Corrected algorithm to add conversion factor from Btu to MMBtu	JP	
2.2 Corrected algorithm to add conversion factor from Btu to kWh/yr (multiply by 1e-3 to divide by 1,000)	SK	
3. Removed measures per note above and reformatted	Franklin Energy Services	8/29/2012
3.1 Renamed measure	JP	2/8/2013

Commercial Food Service - Gas Rack Oven

Version No. 1.1

Measure Overview

Description: This measure includes replacement of commercial gas rack ovens with new high efficiency rack ovens. High efficiency rack ovens achieve higher efficiencies by incorporating timesaving features via sophisticated control packages.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Eday_base - Eday_prop) / Conversion Factor x Days

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $4,933 for single-rack; $5,187 for double-rack (Ref. 2)

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (Btu/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

LBFood = See Table 1; Pounds of food cooked per day (Ref. 2)

Efood = 235 Btu/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 30%; Heavy load cooking energy efficiency (Ref. 2)

Eff_prop = 50% (Ref. 2)

IdleRate_base = See Table 1; Idle Energy Rate (Ref. 2)

IdleRate_prop = See Table 1 (Ref. 2)

OpHrs = 8 hrs/day; Daily operating hours (Ref. 4)

PC_base = See Table 1; Production Capacity (Ref. 2)

PC_prop = See Table 1 (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = See Table 1; Preheat energy (Ref. 2)

E_pre_prop = See Table 1 (Ref. 2)

Days = See Table 2

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: building type, single or double rack

Example:

A high school cafeteria installed a new high efficiency double-rack oven.

Eday_base (Btu/day) = (1,200 lbs/day) x (235 Btu/lb) / (30%) + [65,000 Btu/hr x (8 hrs/day - (1,200 lbs/day / 250 lb/hr) - (15 min / 60 min/hr))] + 100,000 Btu/day = 1,231,750 Btu/day

Eday_prop (Btu/day) = (1,200 lbs/day) x (235 Btu/lb) / (50%) + [35,000 Btu/hr x (8 hrs/day - (1,200 lbs/day / 280 lb/hr) - (15 min / 60 min/hr))] + 85,000 Btu/day = 770,250 Btu/day

Unit Dth Savings per Year = (1,231,750 Btu/day - 770,250 Btu/day) / 1,000,000 Btu/Dth x 200 days/yr = 92.3 Dth

Deemed Input Tables:

Table 1: Oven Characteristics

	Single-Rack Oven	Double-Rack Oven
LBFood (lbs/day)	600	1200
Efood (Btu/lb)	235	235
Eff_base (%)	30%	30%
Eff_prop (%)	50%	50%
IdleRate_base (Btu/hr)	43,000	65,000
IdleRate_prop (Btu/hr)	29,000	35,000
OpHrs (hrs/day)	8	8
PC_base (lbs/hr)	130	250
PC_prop (lbs/hr)	140	280
T_pre (minutes)	20	20
E_pre_base (Btu)	50,000	100,000
E_pre_prop (Btu)	44,000	85,000

Table 2: Operation Hours by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Notes:

There is no code requirement for this technology.

References:

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

2. *Commercial Rack Ovens,* Food Service Equipment Workpaper PGECOFST109 R1, PG&E. June 1, 2009.

3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

4. *Technology Assessment: Ovens,* Food Service Technology Center, 2002. Page 7-22. http://www.fishnick.com/equipment/techassessment/7_ovens.pdf

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/27/2012
1.1 Changed measure name, added single or double rack as required input from customer/contractor	JP	9/12/2013

Commercial Hot Water - Faucet Aerator (1.5 gpm) with Gas Water Heater

Version No. 3.3

Measure Overview

Description: This measure includes replacing an existing faucet aerator with low-flow aerator.

Actions: Replace Working
Target Market Segments: Replace Working
Target End Uses: DHW

Applicable to: Commercial facilities with gas water heaters. Measure includes installation of 1.5 GPM aerators only.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = ((GPM_base - GPM_low) x L x NOPF x Days x DF / GPMfactor) x EPG

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 1)

Unit Participant Incremental Cost = $6.70 (Ref. 6)

Where:

EPG = Density x Specific Heat x (Tfaucet - Tcold) / (ReEff x ConversionFactor)

NOPF = People / Faucets

GPM_base = 1.2 gpm (Ref. 2); Flow rate of existing 2.5 GPM aerator, adjusted for throttled flow uses

GPM_low = 0.94 gpm (Ref. 2); Flow rate of proposed 1.5 GPM aerator, adjusted for throttled flow uses

L = 9.85 min/person/day; Usage time (Ref. 2)

People = Provided by customer; Number of people in facility

Faucets = Provided by customer; Number of faucets in facility

DF = See Table 2; Drain Factor that accounts for uses that are volumetric in nature and aren't affected by low-flow aerators

GPM Factor = See Table 2; Factor accounts for differences in use between commercial and residential applications

Days = See Table 3; Days of operation

Specific Heat = 1.0 Btu / (lb x °F); Specific heat of water

Density = 8.34 lbs / gal; Density of water

Tfaucet = 90°F; Temperature of typical faucet usage (Ref. 2)

Tcold = Average groundwater temperature per Table 1 (Ref. 4)

ReEff = Recovery Efficiency = 75% (gas water heater) (Ref. 2)

Conversion Factor = 1,000,000 Btu/Dth (gas water heater)

Required from Customer/Contractor: confirmation of gas water heater, project location (county), number of people, number of faucets, bath or kitchen faucets.

Example:

Direct installation of a 1.5 GPM faucet aerator in a small office kitchen with gas water heat located in Zone 1. The office has 20 people and 5 faucets.

NOPF = 20 people / 5 faucets = 4.0

EPG = (8.34 lbg/gal) x (1.0 Btu/lb°F) x (90°F - 46.5°F) / (0.75 x 1,000,000) = 0.000484 Dth/gal

Unit Dth Savings per Year = ((1.2 gpm - 0.94 gpm) x (9.85 min/person/day) x (4.0) x (250 days) x 0.75) / 1.0 x 0.000484 Dth/gal = 0.93 Dth saved

Deemed Input Tables:

Table 1: Average groundwater temperatures (Ref. 4).

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3

Table 2: Faucet Characteristics (Ref. 2)

Application	DF	GPMfactor
Kitchen	75%	1.0
Bath	90%	2.5

Table 3: Deemed Annual Hot Water Use by Building Type (Ref. 7)

Building Type	Days Per Year
Small Office	250
Large Office	250
Fast Food Restaurant	365.25
Sit-Down Restaurant	365.25
Retail	365.25
Grocery	365.25
Warehouse	250
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Motel	365.25
Hotel	365.25
Other Commercial	250

Methodology and Assumptions:

Uses algorithms from IL TRM (Ref. 2)

(L), Usage time coincides with the middle of the range (6.74 min/per/day to 13.4 min/per/day) from multiple sources.

GPM_base is a representative baseline flow rate for kitchen and bathroom faucet aerators from mulitple sources.

GPM_low is an average retrofit flow rate for kitchen and bathroom faucet aerators from multiple sources. This accounts for all throttling and differences from rated flow rates.

Notes:

The current standard for kitchen and bathroom aerators is 2.2 GPM, effective 1/1/1994. (Ref. 5)

References:

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values. http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.

2. State of Illinois Energy Efficiency Technical Reference Manual, Page 132-139. July 18, 2012.

3. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates)* for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table

4. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules*
http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

5. Title 10, Code of Federal Regulations, Part 430 - Energy Conservation Program for Consumer Products, Subpart C - Energy and Water Conservation Standards and Their Effective Dates. January 1, 2010

6. 2008 Database for Energy-Efficient Resources, Cost Values and Summary Documentation (updated 6/2/2008 - NR linear fluorescent labor costs typo)
http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.

7. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer, DER	
2. Revised formatting and algorithms	Franklin Energy Services	7/27/2012
2. Update the measure life and measure cost	Franklin Energy Services	7/27/2012
3. Update the algorithm to IL TRM	Franklin Energy Services	8/27/2012
3.1 Update the Peak kW algorithm	Franklin Energy Services	8/28/2012
3.2 Changed Action from Direct Install to Replace Working, changed from 8760 to 8766 hours per year to be consistent with other measures, minor edits.	JP	3/13/2013
3.3 Changed “electric or gas water heater” to “confirmation of gas water heater” in Required Inputs	JP	11/25/2013

Commercial Hot Water - Pre-Rinse Sprayers (1.6 gpm) with Gas Water Heater

Version No. 2.8

Measure Overview

Description: This measure includes retrofit of working standard pre-rinse sprayers with low-flow, 1.6 gpm pre-rinse sprayers in commercial kitchen applications.

Actions: Replace Working
Target Market Segments: Commercial
Target End Uses: DHW

Applicable to: Commercial facilities with kitchens: restaurants, large office buildings, etc, with gas water heaters.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = EPG x WaterSaved / ReEff / ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 5 (Ref. 1)

Unit Participant Incremental Cost = $100 (Ref. 3)

Where:

EPG = SpecificHeat x Density x (Tmix - Tcold)

WaterSaved = (Flow_base x Hours_base - Flow_eff x Hours_eff) x 60 min/hr x Days

SpecificHeat = 1.0 btu / (lb x °F)

Density = 8.34 lbs / gal

Flow_base = 2.23 gal/min (Ref. 1)

Flow_eff = 1.12 gal/min is default (Ref.1)

Hours_base = 0.44 hr/day (Ref. 1)

Hours_eff = 0.60 hr/day (Ref. 1)

Days = See Table 2

Tmix = 105 °F; spray water temperature (Ref. 1)

Tcold = Average groundwater temperature per Table 1 (Ref. 2)

ReEff = 0.75; recovery efficiency (gas water heater) (Ref. 3)

ConversionFactor = 1,000,000 Btu/Dth (gas water heater)

Required from Customer/Contractor: Confirmation of gas water heater, building type, project location (county)

Example:

A direct install crew has installed a low-flow pre-rinse spray valve in a local sit-down restaurant kitchen located in Zone 2. The existing water heater is gas.

WaterSaved = (2.23 gal/min x 0.44 hr/day - 1.12 gal/min x 0.60 hr/day) x 60 min/day x 365.25 day/yr = 6776 gal/yr

EPG = (1 Btu/lb°F) x (8.34 lbs/gal) x (105°F - 49.1°F) = 466.2 Btu/gal

*Unit Dth Savings per Year = 466.2 Btu/gal * 6,776 gal/yr / 0.75 / (1,000,000 Btu/Dth) = 4.2 Dth*

Deemed Input Tables:

Table 1: Average groundwater temperatures (Ref. 2).

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3

Table 2: Deemed Annual Hot Water Use by Building Type (Ref. 6)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
Other Commercial	250

Methodology and Assumptions:

The following building types were considered not to apply to this measure: Small Office, Retail, Warehouse and Motel

Notes:

The current flow standard for Pre-Rinse Sprayers is 1.6 GPM (Ref. 4)

The Federal Energy Management Program (FEMP) requires the federal government purchase and install pre-rinse spray valves with 1.25 gpm in federal buildings. (Ref.7)

References:

1. IMPACT AND PROCESS EVALUATION FINAL REPORT for CALIFORNIA URBAN WATER CONSERVATION COUNCIL 2004-5 PRE-RINSE SPRAY VALVE INSTALLATION PROGRAM (PHASE 2)

2. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules*
http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

3. State of Illinois Energy Efficiency Technical Reference Manual, June 1st, 2012. Pages 109-113.

4. Title 10, Code of Federal Regulations, Part 431 - Energy Efficiency Program for Certain Commercial and Industrial Equipment, Subpart O - Commercial Prerinse Spray Valves. January 1, 2010.

5. No demand savings are claimed for this measure since there is insufficient peak coincident data.

6. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

7. FEMP Designated Product: Pre-Rinse Spray Valves, Purchasing Specification for Energy Efficient Products, FEMP, December 2008.

Documentation Revision History:

Version / Description	Author	Date
1. Put measure together	Franklin Energy Services	7/23/2012
2.0 Add building types and Days variable	Franklin Energy Services	8/6/2012
2.1 Add Flow rate as a variable	Franklin Energy Services	8/6/2012
2.2 Changed the hot water set point from 120°F to 105°F	Franklin Energy Services	8/28/2012
2.3 Added building type to customer/contractor inputs, changed Applicable text	JP	3/25/2013
2.4 Renamed Tset to Tmix, reformulated savings algorithms for consistency with aerators, changed annual hours from 8760 to 8766 and days/yr from 365 to 365.25 for consistency with other measures, changed example accordingly	JP	3/27/2013
2.5 Electric water heater recovery efficiency changed from 0.97 to 0.98 per FES recommendation	JP	4/5/2013
2.5 Example updated accordingly	JP	4/5/2013
2.6 Updated example from electric to gas savings, changed "electric or gas water heater" to "confirmation of gas water heater" in Required Inputs	JP	11/25/13
2.7 Updated to clarify that spec applies to installation of 1.6 gpm sprayers, removed ability to use flow rate of new sprayer as 1.12 gpm is actual average flow rate in field measured as part of evaluation study in Ref. 1. Corrected example to specify gas water heater.	JP	4/8/14
2.8 Added federal government purchase requirements and reference.	Franklin Energy Services	7/31/2014

Commercial Hot Water – Gas Water Heater

Version No. 6.6

Measure Overview

Description: This measure includes replacement of failed or working gas water heaters in existing commercial facilities with high efficiency gas units, as well as installation of high efficiency gas water heaters in new commercial facilities. Includes installation of high efficiency instantaneous gas water heaters.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: DHW

Applicable to: Storage or instantaneous gas water heaters installed in commercial applications.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = EnergyToHeatWater x (1 / Eff_Base - 1 / Eff_High)/ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years): see Table 4

Unit Participant Incremental Cost: see Table 5

Where:

EnergyToHeatWater = SpecificHeat x Density x GalPer1000SqftPerDay x Area/1000 x DaysPerYear x (Tset - Tcold)

SpecificHeat = 1.0 btu / (lb x °F)

Density = 8.34 lbs / gal

GalPer1000SqftPerDay = Deemed gallons per 1,000 square foot per day based on building type per Table 2

DaysPerYear = Days per year of operation per Table 2

Area = Minimum of:

- Floor area served by the water heater in ft^2, provided by customer/contractor
- Tank Size / (Min Storage Capacity per 1,000 sq ft, see Table 2) x 1000, the maximum floor area that could be served by the water heater in ft^2 based on tank size (not applicable for instantaneous units)

- (Input Btu/h / 1000) / (Min Heating Capacity per 1,000 sq ft, see Table 2) x 1000, the maximum floor area that could be served by the water heater in ft^2 based on heating capacity

Tset = 140 °F (Ref. 8)

Tcold = Average groundwater temperature per Table 1

Eff_Base = Efficiency of standard water heater, expressed as Energy Factor (EF) or thermal efficiency per Table 3.

Eff_High = Efficiency of efficient water heater, expressed as Energy Factor (EF) or thermal efficiency consistent with Eff_Base.

ConversionFactor = 1,000,000 Btu/Dth (gas water heaters)

Required from Customer/Contractor: Water heater type (gas storage or gas instantaneous), input Btu/h, efficiency of new water heater, tank size in gallons, building type, square footage, project location (county)

Example:

A 1,300 ft^2 fast food restaurant in Zone 2 installed a new 60-gallon, 40,000 Btu/h gas storage water heater with an EF of 0.67

Max area based on tank size = 60/38.9 x 1000 = 1,542 ft^2
Max area based on heating capacity = (40000/1000)/34.4 x 1000 = 1,163 ft^2

Area = minimum (1300, 1542, 1163) = 1,163 ft^2

EnergyToHeatWater = 1 x 8.34 x 549.2 x 1163/1000 x 365.25 x (140 - 49.1) = 176,860,318 Btu/yr

Eff_Base = 0.67 – (0.0019 x 60) = 0.56

Unit Dth Savings per Year = 176,860,318 x (1/0.56 - 1/.67) /1,000,000 = 51.9 Dth

Deemed Input Tables:

Table 1: Average groundwater temperatures (Ref. 1)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3

Table 2: Deemed Annual Hot Water Use by Building Type, Minimum Storage Capacity and Heating Capacity (Ref. 2)

Building Type	Days Per Year	Annual Hot Water Load (Gal per 1,000 Sqft Per Day)	Minimum Storage Capacity (Gal per 1,000 Sqft)	Minimum Heating Capacity (kBtu/hr per 1,000 Sq Ft)
Small Office	250	2.3	0.7	0.6
Large Office	250	2.3	0.7	0.6
Fast Food Restaurant	365.25	549.2	38.9	34.4
Sit-Down Restaurant	365.25	816.0	36.0	31.9
Retail	365.25	2.0	0.6	0.6
Grocery	365.25	2.2	0.7	0.6
Warehouse	250	1.0	0.3	0.3
Elementary School	200	5.7	4.6	4.0
Jr. High/High School/College	200	17.1	7.6	6.7
Health	365.25	342.0	21.4	27.8
Motel	365.25	100.0	23.9	21.1
Hotel	365.25	30.8	8.8	7.8
Other Commercial	250	0.7	0.2	0.2

Table 3: Deemed baseline efficiency based on ASHRAE 90.1-2004, Table 7.8, as adopted by MN Commercial Energy Code (Ref. 3)

Equipment Type	Input Btu/h	Subcategory	Minimum Efficiency	Efficiency Metric
Gas Storage Water Heaters	≤75,000 Btu/h	≥ 20 gal	0.67 - (0.0019 x gal)	Energy Factor
	>75,000 Btu/h	< 4,000 (Btu/h)/gal	0.80	Thermal Efficiency
Gas Instantaneous Water Heaters*	>50,000 Btu/h and <200,000 Btu/h	≥4,000 (Btu/h)/gal and <2 gal	0.67 - (0.0019 x gal)	Energy Factor
	≥ 200,000 Btu/h	≥4,000 (Btu/h)/gal	0.80	Thermal Efficiency

** "gal" refers to volume of buffer tank in gallons*

Table 4: Measure Lifetime by Type (Ref. 4)

Equipment Type	Lifetime (years)
Gas Storage Water Heaters	11
Gas Instantaneous Water Heaters	20

Table 5: Incremental Cost by Type

Equipment Type	Input Btu/h	Incremental Cost	
Gas Storage Water Heaters	≤75,000 Btu/h	$0.00	(Ref. 5)
	>75,000 Btu/h	$1,350.00	(Ref. 6)
Gas Instantaneous Water Heaters*	>50,000 Btu/h and <200,000 Btu/h	$0.00	(Ref. 5)
	≥ 200,000 Btu/h	$1,800.00	(Ref. 6)

Notes:

Current water heater efficiency standards are given in Table 3

References:

1. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules*

http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

2. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.

3. Minnesota Commercial Energy Code, Minn. Rules ch. 1323.0780 Table 7.8, Performance Requirements for Water Heating Equipment.

4. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008

5. Values are from DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Tables 8.2.13-14, 8.2.16

http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf

*The values are interpreted with explanation in the "Cost Info" tab of measure worksheet.

6. ActOnEnergy Technical Resource Manual, Standard Measures, 5/31/2011. Pages 278, 284 and 286.

7. "Lower Water Heating Temperature for Energy Savings," Department of Energy website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Accessed 7/26/12.

8. "To minimize the growth of Legionella in the system, domestic hot water should be stored at a minimum of 60°C (140°F) " http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_7.html#5. Section III, Chapter 7; V.C.3.a

Documentation Revision History:

Version / Description	Author	Date
4. Original from Nexant with extraneous tabs hidden	Nexant	
5. Updated baseline efficiencies to reflect 2009 MN Commercial Energy Code; updated supply water temperature per Eno Scientific groundwater temp map	JP	
5.1 Corrected formula to include square footage	JP	
5.2 Corrected deemed baseline efficiency for gas instantaneous water heaters	JP	
5.3 Changed label "Gal Per SqFt" in Table 2 to "Gal Per 1,000 SqFt", corrected error in algorithm to use Days Per Year from Table 2 instead of 365, corrected labeling error (changed EF_Efficient to Eff_High)	JP	
5.4 Changed water density from 8.35 to 8.34 to be consistent with residential water heater spec	JP	
5.5 Changed Eff_High description to reference efficient water heater; EF or thermal efficiency should be consistent with Eff_Base	SK	
6. Updated the groundwater temperatures	Franklin Energy Services	7/23/2012
6.1 Added electric water heater data and example	Franklin Energy Services	7/23/2012
6.2 Changed the measure lifetimes to reflect DEER EUL	Franklin Energy Services	7/23/2012
6.3 Updated incremental costs	Franklin Energy Services	7/23/2012
6.3 Changed hot water temp to 140 oF per OSHA guidelines for prevention of Legionnaire's contamination	Franklin Energy Services	3/20/2013
6.4 Added Replace Working to action types	JP	3/22/2013
6.4 Changed title from Commercial Electric Water Heaters to Commercial Hot Water - Water Heater	JP	3/22/2013
6.4 Changed Applicable To text	JP	3/22/2013
6.4 Revised require inputs to work with gas or electric water heaters	JP	3/22/2013
6.4 Changed 8760 to 8766 hours and 365 days to 365.25 to be consistent with other measures, changed example accordingly	JP	3/22/2013

6.5 Updated example to gas water heater	JP	11/25/13
6.6 Corrected description to refer only to replacement with gas water heaters, added CenterPoint Energy method to adjust area if tank size or heating capacity is insufficient to meet hot water load, modified example accordingly, corrected Required Inputs	JP	1/3/14

Residential Hot Water - Drainpipe Heat Exchanger with Gas Water Heater

Version No. 2.4

Measure Overview

Description: This measure includes installing a drainpipe heat exchanger to a residential or multi-family building to recover heat from heated water going down the building's drain.

Actions: Modify
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size gas water heaters.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = EnergyToHeatWater / Eff x SavingsFactor / ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 20 (Ref. 1)

Unit Participant Incremental Cost = $742 (Ref. 1)

Where:

EnergyToHeatWater = SpecificHeat x Density x Gal/Day x 365 Days/Year x (Tset - Tcold)

SpecificHeat = 1.0 btu/(lb x °F)

Density = 8.34 lbs/gal

Gal/Day = See Table 2; Average gallons per day of hot water usage (gal/day)

Tset = 120 °F (Ref. 4)

Tcold = Average groundwater temperature per Table 1 (Ref. 3)

Eff = Energy Factor of water heater (provided by customer/contractor)

SavingsFactor = 0.25 (Ref. 2)

ConversionFactor = 3,412 Btu/kWh (electric water heater) or 1,000,000 Btu/Dth (gas water heater)

Required from Customer/Contractor: confirmation of gas water heater, water heater efficiency (EF), building type (single family or multi family*), project location (county).

** Includes buildings with 2+ units and townhomes*

Example:

A single-family customer in Zone 1 has installed a drain pipe heat exchanger to recover wasted energy from the house's drain line. Their gas water heater has an EF of 0.68.

EnergyToHeatWater = (1 Btu/lb°F) x (8.34 lbs/gal) x (52.7 gal/day) x (365 days/yr) x (120°F - 46.5°F) = 11,791,169 Btu/yr

Unit Dth Savings per Year = (11,791,169 Btu/yr) / (0.68) x (25%) / (1,000,000 Btu/Dth) = 4.3 Dth

Deemed Input Tables:

Table 1: Average groundwater temperatures (Ref. 3)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3

Table 2: Daily Hot Water Usage by Building Type

Building Type	Daily Gal/person (Ref. 5)	Num_People (Ref. 6)	Total Daily Hot Water Use (gal/day)
Single-family	20.4	2.59	52.7
Multi-family*	18.7	2.17	40.5

** Includes buildings with 2+ units and townhomes*

Notes:

There are no current efficiency standards for this technology.

References:

1. State of Ohio Energy Efficiency Technical Reference Manual, 2010. Prepared by Vermont Energy Investment Corporation. Page 78.

2. Drain pipe heat exchange savings estimates are based on study findings reported in a communication from J. J. Tomlinson, Oak Ridge Buildings Technology Center, to Marc LaFrance, DOE Appliance and Emerging Technology Center, DOE, August 24, 2000, suggesting 25 to 30% of water heating consumption savings potential. The lower end of the savings scale was chosen for this report, assuming ideal installation for the study.

3. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules*

http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

4. "Lower Water Heating Temperature for Energy Savings," Department of Energy website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Accessed 7/26/12. The webpage referenced by the link has since changed and is no longer relevant.

5. Interpolated values from Table 38, Ohio Technical Reference Manual. October 15, 2009. Page 52.

6. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates)* for the state of MN.

http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=tabl

Documentation Revision History:

Version / Description	Author	Date
1. Derived from ResidentialElectricDHW_v03.2 and ResidentialGasDHW_v03.2 which were based on Nexant's original spec.	Joe Plummer, DER	
2. Updated the groundwater temperatures, see "Water Temps" tab	Franklin Energy Services	7/23/2012
2.1 Added example	Franklin Energy Services	7/23/2012
2.2 Updated the measure cost	Franklin Energy Services	7/23/2012
2.3 Changed action type to Modify, changed "electric or gas water heater" to "confirmation of gas water heater" in Required Inputs	JP	11/25/2013
2.4 Added building type to required inputs, added footnotes clarifying multifamily definition	JP	3/18/2014

Residential Hot Water - Faucet Aerator (1.5 gpm) with Gas Water Heater

Version No. 3.5

Measure Overview

Description: This measure includes replacing an existing faucet aerator with low-flow aerator.

Actions: Replace Working
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size gas water heaters

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = WaterSaved x Density x SpecificHeat x (Tfaucet – Tcold) / ReEff / ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 1)

Unit Participant Incremental Cost = $6.70 (Ref. 6)

Where:

WaterSaved = Flow_diff x Vmin x (Num_People) x 365 days/year

Flow_diff = 1.0 GPM (i.e. 2.5 GPM replaced with 1.5 GPM)

Vmin = 1.125 minutes; the number of minutes of faucet use per adjusted number of bedrooms per day (an average of the following values: 1.5 minutes (kitchen) and 0.75 minutes (bathroom)) (Ref. 2)

Num_People = Number of people per household per Table 2

SpecificHeat = 1.0 btu / (lb x °F)

Density = 8.34 lbs / gal

Tfaucet = 80°F; Temperature of typical faucet usage (Ref. 2)

Tcold = Average groundwater temperature per Table 1 (Ref. 4)

ReEff = 0.75; recovery efficiency (gas water heater) (Ref. 7)

Required from Customer/Contractor: confirmation of gas water heater, building type (single family or multi family*), project location (county)

** Includes buildings with 2+ units and townhomes*

Example:

Direct installation of a 1.5 GPM faucet aerator in an apartment with gas water heat located in Zone 1.

WaterSaved (gal/yr) = (1.0 gal/min) x (1.125 min) x (2.17 people) x 365 days/year = 891 gallons saved per year

Unit Dth Savings per Year = (891 gal) x (8.34 lbs/gal) x (1.0 Btu/lb°F) x (80°F – 46.5°F) / 0.75 /1,000,000 Btu/Dth = 0.33 Dth saved

Deemed Input Tables:

Table 1: Average groundwater temperatures (Ref. 4).

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3

Table 2: People per Household (Ref. 3).

Application	Num_People
Single-Family	2.59
Multi-Family*	2.17

** Includes buildings with 2+ units and townhomes*

Methodology and Assumptions:

Uses algorithms from Efficiency Vermont TRM (Ref. 2)

The “BR + 1” from Ref. 2 is assumed to equal the number of people per household or unit; People per household will be used instead of BR + 1.

Notes:

The current standard for kitchen and bathroom aerators is 2.2 GPM, effective 1/1/1994. (Ref. 5)

FOE uses 8 therms/187 kWh for Commercial applications

ActOnEnergy TRM has 82 kWh, 6.1 therms, and 15 years

IL TRM uses 1.89 therms/ 42 kWh

NY TRM has 314 kWh, 17 therms

Ohio TRM (VEIC) 2010 uses 24.5 kWh / .109 MMBtu

References:

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values. http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.

2. Efficiency Vermont Technical Reference User Manual, 2/19/2010.

3. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates)* for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table

4. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules* http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

5. Title 10, Code of Federal Regulations, Part 430 – Energy Conservation Program for Consumer Products, Subpart C – Energy and Water Conservation Standards and Their Effective Dates. January 1, 2010

6. 2008 Database for Energy-Efficient Resources, Cost Values and Summary Documentation (updated 6/2/2008 – NR linear fluorescent labor costs typo) http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.

7. State of Illinois Energy Efficiency Technical Reference Manual, June 1st, 2012. Pages 109-113.

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer, DER	
2. Revised formatting and algorithms	Franklin Energy Services	7/27/2012
2. Update the measure life and measure cost	Franklin Energy Services	7/27/2012
3. Corrected Energy Factor equations	Franklin Energy Services	3/20/2013
3.1 Changed action from Direct Install to Replace Working	Joe Plummer, DER	4/5/2013
3.2 Removed extra multiplication sign following Eff in savings algorithms	Joe Plummer, DER	8/28/2013
3.3 Changed "electric or gas water heater" to "confirmation of gas water heater" in Required Inputs, changed efficiency to recovery efficiency of 0.75 and updated example accordingly	JP	11/25/13
3.4 Added residence type (single family or multi family) to required inputs	JP	1/3/14
3.5 Removed “owner-occupied” from single-family and “renter-occupied” from multifamily in Table 2, added footnotes clarifying multifamily definition.	JP	3/11/14

Residential Hot Water – Gas Water Heater

Version No. 4.1

Measure Overview

Description: This measure includes replacement of failed or working storage-type, domestic gas-fired storage and instantaneous water heaters in residential and multifamily buildings, as well as installation of gas-fired storage or instantaneous water heaters in new construction.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size gas water heaters

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = Energy to Heat Water x (1/EF_minimum – 1/EF_efficient) / ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 for storage models; 20 for tankless models (Ref. 3)

Unit Participant Incremental Cost = See Table 4

Where:

EnergyToHeatWater = Specific Heat x Density x Gal_Person x People x 365 Days/Year x (Tset – Tcold)

SpecificHeat = 1.0 btu / (lb x °F)

Density = 8.34 lbs / gal

Gal_Person = See Table 2; Daily hot water usage per person

People = See Table 3; number of people per household

Tset = 120 °F (Ref. 7)

Tcold = Average groundwater temperature per Table 1

EF_Minimum = 0.67 – 0.0019 x (Tank Size in Gallons): storage units

= 0.62 – 0.0019 x (Rated Storage Volume in gallons): instantaneous units

EF_Efficient = Efficiency (energy factor) of new water heater (0-1);

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: confirmation of gas water heater, tank size in gallons, new water heater efficiency (EF), single-family or multifamily*, project location (county)

** Includes buildings with 2+ units and townhomes*

Example:

A single-family customer in Zone 2 has installed a new 50-gallon gas-fired water heater (EF = 0.7) to replace their previous gas-fired storage water heater.

EF_Minimum = 0.67 - 0.0019 x 50 gallons = 0.575

Energy To Heat Water = (1 Btu/lb°F) x (8.34 lbs/gal) x (20.4 gal/person) x (2.59 people) x (365 d/yr) x (120°F - 49.1°F) = 11,403,419 Btu/yr

Unit Dth Savings per Year = (11,403,419 Btu/yr) x (1/0.575 - 1/0.70) / (1,000,000 Btu/Dth) = 3.5 Dth

Deemed Input Tables:

Table 1: Average groundwater temperatures (Ref. 4)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3

Table 2: Daily Hot Water Usage per Person (Ref. 8)

Application	(Gal/day)/person
Single-Family	20.4
Multi-Family*	18.7

** Includes buildings with 2+ units and townhomes*

Table 3: People per Household (Ref. 9)

Application	Num_People
Single-Family	2.59
Multi-Family*	2.17

** Includes buildings with 2+ units and townhomes*

Table 4: Incremental Cost by Type (Ref. 4)

Type of Water Heater	Incremental Cost
Power-Vented, Gas-Fired, Storage	$577.00
Condensing, Gas-Fired, Storage	$814.00
Instantaneous Gas	$1,096.60

Notes

Table 5: Current Equipment Standards, effective for products manufactured from January 20, 2004 through April 15, 2015 (Ref. 5)

Type of Equipment	Energy Factor
Gas-Fired Storage Water Heaters	0.67 - (0.0019 x Rated Storage Volume in gallons)
Instantaneous Gas-Fired Water Heaters	0.62 - (0.0019 x Rated Storage Volume in gallons)

Table 6: Future Equipment Standards, effective for products manufactured on or after April 16, 2015 (Ref. 6)

Type of Equipment	Energy Factor
Gas-Fired Storage Water Heaters, ≤ 55 gallons	0.675 - (0.0015 x Rated Storage Volume in gallons)
Gas-Fired Storage Water Heaters, > 55 gallons	0.8012 - (0.00078 x Rated Storage Volume in gallons)
Instantaneous Gas-Fired Water Heaters	0.82 - (0.0019 x Rated Storage Volume in gallons)

References

1. Daily hot water usage is based on CEE's tankless water heater field study in Mpls/St. Paul (2008-2010); Supported by Focus on Energy's Residential Deemed Savings Review, page 4.

2. US DOE Building America Program. Building America Analysis Spreadsheet, Standard Benchmark DHW Schedules http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

3. Incremental water heater costs, water heater lifetime from NW Council-RTF Residential DHW-Efficient Tanks deemed savings, v 2.0

4. Values are from DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Tables 8.2.13-14, 8.2.16 (http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf). The values are interpreted with explanation in the "Cost Info" tab of this worksheet.

5. Title 10, Code of Federal Regulations, Part 430 - Energy Conservation Program for Consumer Products, Subpart C - Energy and Water Conservation Standards and Their Effective Dates. January 1, 2010

6. Energy Conservation standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters: Final Rule, Federal Register, 75 FR 20112, April 16, 2010.

7. "Lower Water Heating Temperature for Energy Savings," Department of Energy website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Accessed 7/26/12.

8. Interpolated values from Table 38, Ohio Technical Reference Manual. October 15, 2009. Page 52.

9. U.S. Census Bureau, Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates) for the state of MN.

http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer, DER	
2.0 Updated the groundwater temperatures	FES	7/23/2012
2.1 Added example	FES	7/23/2012
2.2 Amended description, measure requirements and EF_Efficient	FES	7/23/2012
2.3 Updated the incremental costs	FES	7/23/2012
3.0 Updated the hot water usage	FES	8/6/2012
4.0 Updated measure lifetimes for tankless water heaters	FES	3/20/13
4.1 Added footnotes clarifying multifamily definition, changed “tankless” to “instantaneous” since some instantaneous water heaters have small buffer tanks	JP	3/12/2014

Residential Hot Water – Gas Water Heater Setback

Version No. 3.2

Measure Overview

Description:

This measure involves turning the water heater set point temperature to 120°F on residential storage-type gas water heaters. The action must be performed by a utility representative on site during a home energy audit or other home visit.

The existing temperature set point is assumed to be 130°F.

Actions: Operations and Maintenance
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size gas water heaters

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = SpecificHeat x Density x Gal_Person x People x 365.25 x (Tset - Tin) x Savings_Factor/ Eff / ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 2 (Ref. 2)

Unit Participant Incremental Cost = $0

Where:

SpecificHeat = 1.0 btu / (lb x °F)

Density = 8.34 lbs / gal

Gal_Person = See Table 2; Daily hot water usage per person

People = See Table 3; Number of people per household

Tset1 = 130 °F (assumed average starting temperature)

Tin = Average groundwater temperature per Table 1

Eff (gas) = 0.59 (2004 Federal minimum Energy Factor for 40 gal tank = 0.67 - 0.0019 x 40)

Eff (elec) = 0.92 (2004 Federal minimum Energy Factor for 40 gal tank = 0.97 - 0.00132 x 40)

ConversionFactor = 3,412 Btu/kWh (electric water heater) or 1,000,000 Btu/MMBtu (gas water heater)

Savings_Factor = 4% (Ref. 3)

Required from Customer/Contractor: confirmation of gas water heater, project location (county), building type (single family or multi-family*)

** Includes buildings with 2+ units and townhomes*

Example:

A direct install team reduces the set point of a gas water heater in a single-family home in Zone 1.

Unit Dth Savings per Year = (1.0 Btu/lb°F) x (8.34 lb/gal) x (20.4 gal/day/person) x (2.59 people) x (365.25 day/yr) x (130°F - 46.5°F) x 4% / (0.59) / (1,000,000 Btu/Dth) = 0.91 Dth saved

Deemed Input Tables:

Table 1: Average groundwater temperatures (Ref. 4)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3

Table 2: Daily Hot Water Usage per Person (Ref. 6)

Location	Gal/day/person
Single Family	20.4
Multi Family*	18.7

** Includes buildings with 2+ units and townhomes*

Table 3: People per Household (Ref. 7)

Application	Num_People
Single Family	2.59
Multi Family*	2.17

** Includes buildings with 2+ units and townhomes*

Methodology and Assumptions:

The savings from lowering the temperature setpoint 10°F is 3% to 5% of the overall domestic hot water energy. (Ref. 3)

The existing temperature is assumed to be 130°F (Ref. 5)

Notes:

There are no current energy standards for this measure.

The previous algorithm assumed that all hot water uses are done at max temperature, when in reality only a few are (i.e. clothes washer, dishwasher, misc. cleaning, etc.). The result of this was that the savings was being overestimated (i.e. 446 kWh, resulting in ~13% overall DHW savings). The IL TRM however, only accounts for the aforementioned uses and ignores the reduction in standby losses by lowering the delta T. The result of this is that the savings is underestimated (i.e. 49 kWh). The DOE estimates a savings that is between these two values. The savings value given by DOE estimates are supported by Ref. 2 (Efficiency Vermont TRM).

The excel algorithms yield a savings of 158 kWh and 0.84 Dth, which is within 4% of the values for Zone 1-single-family applications. The difference in savings will increase in zones 2 and 3 and in multi-family applications.

References:

1. Daily hot water usage is based on CEE's tankless water heater field study in Mpls/St. Paul (2008-2010); Supported by Focus on Energy's Residential Deemed Savings Review, page 4.

2. Efficiency Vermont Technical Reference User Manual (TRM), 2/19/2010. Page 409. This value is supported by the Illinois Technical Reference User Manual, 2012.

3. Average of 3-5% savings values on DOE website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Accessed 7/2

4. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules*

http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

5. Franklin Energy Services internal value.

6. Interpolated values from Table 38, Ohio Technical Reference Manual. October 15, 2009. Page 52.

7. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Commnity Survey 1-Year Estimates)* for the state of MN.

http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table

Documentation Revision History:

Version / Description	Author	Date
1. Originally part of ResidentialGasDHW_v03.2 which was derived from Nexant spec; changed algorithm to assume an average starting and final temperature rather than using an	Joe Plummer, DER	

unsupported savings factor		
2.0 Updated algorithm to use Savings_Factor of 4%	Franklin Energy Services	7/26/2012
2.1 Updated measure lifetime per Ref. 2	Franklin Energy Services	7/27/2012
3.0 Updated the hot water usage to be consistent with the hot water heater measure algorithm	Franklin Energy Services	8/6/2012
3.1 Changed action type to Modify, changed "electric or gas water heater" to "confirmation of gas water heater" in Required Inputs, changed example to compute gas savings instead of electric	JP	11/25/2013
3.2 Added footnotes clarifying multifamily definition. In Dth algorithm, replaced Gal/Day with Gal_Person x People.	JP	3/18/2014

Residential Hot Water - Low Flow Showerheads (1.5 gpm) with Gas Water Heater

Version No. 3.3

Measure Overview

Description: This measure involves replacing a standard showerhead with a low flow showerhead.

Actions: Replace Working
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size gas water heaters.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = WaterSaved x Density x SpecificHeat x (Tshower - Tcold) / ReEff / ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 5)

Unit Participant Incremental Cost = $12 (Ref. 4)

Where:

WaterSaved = Flow_reduction x ShowerWater x Num_People x SPCD x 365 days/year / SPH

Flow_reduction = 40% (i.e. 2.5 GPM replaced with 1.5 GPM; (2.5-1.5)/2.5 = 0.40)

ShowerWater = 17.2 gallons; daily hot water use per shower per person (Ref. 3)

Num_People = Number of people per household per Table 2

SPCD = 0.75; Showers per capita per day (Ref. 4)

SPH = Showerheads per Household per Table 3

SpecificHeat = 1.0 Btu/(lb°F)

Density = 8.34 lbs / gal

Tshower = 105°F; Temperature of typical shower usage (Ref. 2)

Tcold = Average groundwater temperature per Table 1

ReEff = 0.75; recovery efficiency (gas water heater) (Ref. 7)

ConversionFactor = 1,000,000 Btu/MMBtu (gas water heater)

Required from Customer/Contractor: electric or gas water heater, residence type (single-family or multi-family*), project location (county)

** Includes buildings with 2+ units and townhomes*

Example:

Direct installation of a low-flow showerhead in an apartment with gas water heat located in Zone 3.

WaterSaved (gal/yr) = (40%) x (17.2 gal/person) x (2.17 people/household) x 0.75 SPCD x 365 days/year / 1.3 SPH = 3,144 gallons saved per year

Unit Dth Savings per Year = (3,144 gal) x (8.34 lbs/gal) x (1 Btu/lb°F) x (105°F - 51.3°F) / 0.75 / 1,000,000 Btu/Dth = 1.9 Dth saved

Deemed Input Tables:

Table 1: Average groundwater temperatures (Ref. 2).

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3

Table 2: People per Household (Ref. 1).

Application	Num_People
Single Family	2.59
Multi Family*	2.17

** Includes buildings with 2+ units and townhomes*

Table 3: Showerheads per Household (Ref. 4).

Application	SPH
Single Family	1.79
Multi Family*	1.30

** Includes buildings with 2+ units and townhomes*

Methodology and Assumptions:

Algorithm is based on the Illinois TRM (Ref. 4), but has been modified with regard to existing water usage estimation. The original IL TRM calculation was estimating fairly high pre-retrofit water usages, so 11.6 gal/day (Ref. 3) has been used in an effort to temper the results.

Notes:

The current flow standard for showerheads is 2.5 GPM (Ref. 6)

References:

1. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates)* for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table

2. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules*

http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

3. Mayer P., DeOreo W., et.al. 1999. Residential end Uses of Water, American water Works Association Research Foundation.

4. Illinois Technical Reference Manual, 6/1/12. Pages 419-426.

5. Table C-6, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. Evaluations indicate that consumer dissatisfaction may lead to reductions in persistence, particularly in Multi-Family,

http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf

6. Title 10, Code of Federal Regulations, Part 430 - Energy Conservation Program for Consumer Products, Subpart C - Energy and Water Conservation Standards and Their Effective Dates. January 1, 2010

7. State of Illinois Energy Efficiency Technical Reference Manual, June 1st, 2012. Pages 109-113.

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer	
2. Changed algorithm per IL TRM and modified the HW usage estimates	Franklin Energy Services	7/31/2012
2. Changed Measure Lifetime from 7 to 10	Franklin Energy Services	7/31/2012
3. Updated ShowerWater description to read "shower water…" instead of "hot water…"	Franklin Energy Services	1/4/2013
3.1 Changed Action type from Direct Install to Replace Working	Joe Plummer	4/8/2013
3.1 Added residence type to list of required inputs from customer/vendor	Joe Plummer	4/8/2013
3.1 Changed description of Tshower from "typical faucet usage" to "typical shower usage"	Joe Plummer	4/8/2013
3.1 Changed "Required Inputs from Direct Installer" to "Required Inputs from Customer/Contractor"	Joe Plummer	4/8/2013
3.2 Changed action type to Modify, changed "electric or gas water heater" to "confirmation of gas water heater" in Required Inputs, changed efficiency to recovery efficiency of 0.75 and updated example accordingly	JP	11/25/2013
3.3 Added footnotes clarifying multifamily definition	JP	3/18/2014

Residential Hot Water - Pipe Insulation with Gas Water Heater

Version No. 2.3

Measure Overview

Description: This measure includes installing pipe insulation on un-insulated piping of a gas water heating system.

Actions: Modify
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family, duplexes and townhomes with gas water heaters.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Qloss_base - Qloss_insul) x Hours x Length / ConversionFactor / Eff

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 13 (Ref. 3)

Unit Participant Incremental Cost = $3.63 (Ref. 4)

Where:

Qloss_base = See Table 1 for values. Heat loss (Btu/ft) from bare piping; See "Btu per Foot" tab for explanation.

Qloss_insul = See Table 1 for values. Heat loss (Btu/ft) from insulated piping; See "Btu per Foot" tab for explanation.

T_hot = 120°F; (Ref. 2; to be consistent with other DHW measures)

T_ambient = 60°F (Ref. 1)

Eff = 0.59

Hours = 4,823 hours; Hours when outside air temperature is above building balance point. Heat loss from pipe is wasted. (Ref. 5)

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: length of pipe insulation (linear feet), confirmation of gas water heater

Example:

A customer in Zone 1 installed R-2 insulation on one foot of un-insulated hot water piping

Unit Dth Savings per Year = (36.9 Btu/ft - 6.9 Btu/ft) x 4,823 hours x 1 ft. / 1,000,000 Btu/Dth / 0.59 = 0.267 Dth

Deemed Input Tables:

Table 1: Average Heat Loss Figures (Ref. 5)

Location	Avg. Heat Loss of Bare Pipe (Btu/ft)	Avg. Heat Loss of Insulated Pipe (Btu/ft)
Zone 1, 2, and 3	**36.9**	**6.9**

Methodology and Assumptions:

Pipes are assumed to be an equal mix of 1/2", 3/4" and 1" sizes.

Insulation is assumed to be R-2 pipe insulation.

Notes:

Section N1103.3 of the 2006 International Residential Code requires mechanical system piping that is capable of carrying fluids above 105 degrees F or below 55 degrees F to be insulated to a minimum of R-2.

References:

1. The ambient temperature is assumed to be 60°F, based on the estimated temperature of a basement where the water heater is assumed to be located.

2. "Lower Water Heating Temperature for Energy Savings," Department of Energy website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Accessed 7/26/12.

3. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values. http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.

4. 2008 Database for Energy-Efficient Resources, Cost Values and Summary Documentation (updated 6/2/2008 - NR linear fluorescent labor costs typo) http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.

5. Xcel Energy 2010-2012 CIP Triennial (Docket No. E, G002/CIP-09-198), Pages 470-477.

Document Revision History:

Version / Description	Author	Date
1. Based on original from Nexant, cleaned up and reformatted	Joe Plummer, DER	
2. Reformatted	Franklin Energy Services	7/26/2012
2.1 Updated the measure cost value/source	Franklin Energy Services	7/31/2012
2.2 Updated the measure lifetime from 15 to 13	Franklin Energy Services	7/31/2012
2.3 Changed Action to Modify, changed Table1 so that same heat loss figures apply to all zones, delete zip code from required inputs, added confirmation of gas water heater to required inputs	JP	11/24/13

Residential HVAC - Electronic Ignition Hearth

Version No. 1.2

Measure Overview

Description: This measure includes replacement of existing hearth/artificial fireplace using a standing pilot with a unit using electronic ignition.

Actions: Replace on Fail, Replace Working
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family homes, duplexes, townhomes, and multi-family homes (including 3- and 4-family homes) with residential type heating equipment

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = P/CF x t

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 (ref. 1)

Unit Participant Incremental Cost = $193 (ref. 1)

Where:

P = Pilot rate in Btu/h, assumed to be 1,000 Btu/h (ref. 2,3)

CF = Conversion factor, CF=1,000,000 Btu/Dth

T = Unit usage, in hrs/year, assumed to be 24 hours x 182.5 days/year = 4,380

Required from Customer/Contractor: none

Example:

An electronic ignition for fireplace installation. Fireplace is used 24 hrs/day, 182.5 days/year.

*Unit Dth Savings per Year = 1000/1000000*24*182.5 = 4.38*

Notes:

Electronic ignition is difficult to install on existing systems and should be undertaken only by someone who is very experienced in this type of work.

References:

1. Online survey and discussion with suppliers and manufacturers
2. Pilot lights add small increase to gas bill, Clark County Public Utilities, March 26, 2006
3. Canadian study Home Energy Magazine, January/February 1997

Documentation Revision History:

Version / Description	Author	Date
1. New measure	Franklin Energy	8/14/2012
1.1 Changed name to Electronic Ignition Hearth	JP	4/3/2013
1.2 Made P and t deemed values	JP	4/3/2013

Residential HVAC - Furnaces and Boilers

Version No. 2.9

Measure Overview

Description: This measure includes replacement of failed or working furnaces and boilers in existing homes with high efficiency units, as well as installation of high efficiency furnaces and boilers in new residences.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family homes, duplexes, townhomes, and multi-family homes (including 3- and 4-family homes) with residential type heating equipment.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = Btuh_input x HDD_{65} x 24 x LF x CF x [1/(T_indoor - T_design)] x (1/Eff_Base - 1/Eff_high) x Eff_Base / 1,000,000

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 20 (Ref. 1)

Unit Participant Incremental Cost: See Table 3

Where:

Btuh_input = the nominal rating of the input capacity of the new furnace or boiler in Btu/h

LF = the load factor, assumed to be 0.77 (implies 30% oversizing) (ref. 2)

CF = correction factor, assumed to be 0.7 (ref. 3)

HDD_{65} = the heating degree-days of the climate zone, see Table 1

T_indoor = the temperature of the indoor conditioned space, assumed to be 65 F

T_design = the equipment design temperature of the climate zone, see Table 1

Eff_base = Efficiency of the baseline, i.e., standard replacement, equipment. Refer to Table 2.

Eff_high = Efficiency (AFUE) of the new furnace or boiler, supplied by customer/contractor.

Required from Customer/Contractor: Equipment type (furnace or boiler), Input Btu/h of new unit, project location (county), AFUE of the new equipment, Action Type (Replace on Fail, Replace Working, or New Construction), building type (single-family or duplex, multifamily*or townhome).

** Multifamily includes buildings with 3 or more units.*

Example:

Retrofit furnace installed in single family home, 94% AFUE, 60,000 btu/h input, Climate Zone 3.

*Unit Dth Savings per Year = 60000 * 7651* 24 * 0.77 * 0.7 * (1/(65 - (-14.5)) * (1/0.80 - 1/0.94) * 0.80 / 1000000 = 11.1 Dth*

Deemed Input Tables:

Table 1: Heating Degrees Days (HDD) and Heating Design Temperature per zone in Minnesota

Minnesota	Zone 1	Zone 2	Zone 3
	(Northern MN)	(Central MN)	(Southern MN/Twin Cities)
HDD_{65} (ref. 4)	9,833	8,512	7,651
T_design (ref. 5)	-22 °F	-16.5 °F	-14.5 °F

Table 2: Deemed baseline efficiency (Ref. 6)

Equipment Type	Building Type*	Existing or New Construction	Baseline Efficiency
Furnace	1F/2F	Existing	80%
Furnace	1F/2F	New Construction	90%
Furnace	TH, MF	Existing	80%
Furnace	TH, MF	New Construction	90%
Boiler	1F/2F, MF or TH	Either	80%

** 1F = single family, 2F = two family, TH = townhomes, MF = multi-family*

Table 3: Incremental Costs (Ref. 7)

Equipment Type	Building Type	Existing or New Con-struction	Equip-ment Cost ($/unit)	Installation Only Cost ($/unit)	Total Installed Cost ($/unit)	Incre-mental Cost ($/unit)
Baseline furnace, 80%	1F/2F, MF or TH	Ex	$1,196	$815	$2,011	$0
New furnace, AFUE ≥ 90% and < 92%	1F/2F, MF or TH	Ex	$1,575	$1,066	$2,641	$630
New furnace, AFUE ≥ 92% and < 94%	1F/2F, MF or TH	Ex	$1,747	$1,066	$2,813	$802
New furnace, AFUE ≥ 94%	1F/2F, MF or TH	Ex	$2,383	$1,066	$3,449	$1,438
Baseline furnace, 80%	1F/2F	NC	$1,196	$815	$2,011	$0
New furnace, AFUE ≥ 90% and < 92%	1F/2F	NC	$1,575	$1,066	$2,641	$630
New furnace, AFUE ≥ 92% and < 94%	1F/2F	NC	$1,747	$1,066	$2,813	$802
New furnace, AFUE ≥ 94%	1F/2F	NC	$2,383	$1,066	$3,449	$1,438
Baseline furnace, 80%	TH	NC	$1,196	$815	$2,011	$0
New furnace, AFUE ≥ 90% and < 92%	TH	NC	$1,575	$1,066	$2,641	$630
New furnace, AFUE ≥ 92% and < 94%	TH	NC	$1,747	$1,066	$2,813	$802
New furnace, AFUE ≥ 94%	TH	NC	$2,383	$1,066	$3,449	$1,438
Baseline boiler, 80%	1F/2F, MF or TH	Either	$1,686	$1,648	$3,334	$0
New boiler, AFUE ≥ 84% and < 90%	1F/2F, MF or TH	Either	$1,937	$2,331	$4,268	$934
New boiler, AFUE ≥ 90%	1F/2F, MF or TH	Either	$2,525	$2,289	$4,814	$1,480

Methodology and Assumptions:

Assumes dedicated exhaust installation for furnaces and chimney liner for water heaters.

Notes:

On May 1, 2013, federal standards prohibiting the sale or import of non-weatherized furnaces with AFUEs of less than 90% were set to take effect in the Northern Region (including MN). This standard has been postponed.

The baseline efficiency source is the Energy Independence and Security Act of 2007 with technical amendments from Federal Register, volume 73, Number 145, Monday, July 28, 2008 for boilers <300,000 Btu/h and is Final Rule, Federal Register, volume 74, Number 139, Wednesday, July 22, 2009 for boiler ≥300,000 Btu/h.

Year	AFUE or TE
Hot Water <300,000 Btu/h < Sept 1, 2012	80% AFUE
Hot Water <300,000 Btu/h ≥ Sept 1, 2012	82% AFUE
Hot Water ≥300,000 & ≤2,500,000 Btu/h	80% TE
Hot Water >2,500,000 Btu/h	82% Ec

References:

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007

http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

2. PA Consulting, KEMA, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that boilers are 30% oversized on average.

3. The correction factor corrects heating usage as building balance points are below 65F, and setback schedules are common. A typical heating degree day correction factor is 0.7. Assuming a typical building balance point temperature of 55F if was found that for a sampling of Minnesota cities HDD55 = 0.7 x HDD65.

4. National Climate Data Center - National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.

5. 2009 ASHRAE Fundamentals Handbook Table 1A Heating and Wind Design Conditions, Heating DB 99.6%

6. US Department of Energy (http://buildingsdatabook.eere.energy.gov/ChapterIntro7.aspx). Though the federal minimum efficiency is 78% there are very few models available at this efficient; a review of AHRI shows that most low efficiency units are 80%.

7. Xcel Energy 2010-2012 CIP Triennial (Docket No. E,G002/CIP-09-198)

Document Revision History:

Version / Description	Author	Date
1. Replaces ResidentialFurnaceMeasures_v01, moved furnace tune-ups to a separate measure, updated baseline efficiencies to reflect decisions in 2010-2012 gas utility triennials	Joe Plummer, DER	
1.1 Added specifications for actions and needed from customer/vendor	Joe Plummer, DER	
1.2 Added missing incremental cost categories	Joe Plummer, DER	
2.1 Changed savings equation	Franklin Energy	7/25/2012
2.2 Added Multi-family buildings to the measure	Franklin Energy	7/25/2012
2.3 Added efficiency standards	Franklin Energy	7/25/2012
2.4 Added references	Franklin Energy	7/25/2012
2.5 Updated equipment costs	Franklin Energy	8/1/2013
2.6 Updated baselines and Federal standard comments due to the postponing of the furnace efficiency standard	Franklin Energy	8/1/2013
2.7 Updated baselines from 78% to 80%	Franklin Energy	8/1/2013
2.8 Added Action Type as Required Input from Customer/Contractor (determines existing or new construction which is needed to determine baseline efficiency)	JP	1/13/14
2.9 Added equipment type to required inputs from customer/contractor. Corrected example to use baseline efficiency of 0.80 instead of 0.78.	JP	3/4/14

Residential HVAC - Furnaces Tune-Up

Version No. 2.5

Measure Overview

Description: A furnace tune-up includes inspection of mechanical/electrical components operation, heat exchanger inspection, measuring and reducing excess air and stack temperature, cleaning burners and combustion chamber.

Actions: O&M
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family homes, duplexes, townhomes, and multi-family homes (including 3- and 4-family homes) with residential type furnace

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = Btuh_input x HDD_{65} x 24 x LF x CF x (1/(T_indoor - T_design))/ 1,000,000 x MF

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 2 (Ref. 1)

Unit Participant Incremental Cost = $175 (default/planning figure; OK to use actual cost of tune-up) (ref.2 TBD)

Where:

Btuh_input= the nominal rating of the input capacity of the furnace in Btu/h

LF= the load factor, assumed to be 0.77 (implies 30% oversizing) (ref. 3)

CF= correction factor, assumed to be 0.7 (ref. 4)

HDD_{65}= the heating degree-days of the climate zone, see Table 1

T_indoor= the temperature of the indoor conditioned space, assumed to be 65 F

T_design= the equipment design temperature of the climate zone, see Table 1

MF= Maintenance saving factor. MF=2%. (ref. 5)

Required from Customer/Contractor: Input Btu/h, project location (county)

Example:

Furnace Tune-up in single family home, 60,000 btu/h input, Climate Zone 3.

*Unit Dth Savings per Year = 60000 * 7651 * 24 * 0.77 * 0.7 * (1/ (65 - (-14.5))) / 1000000 * 0.02= 1.49*

Deemed Input Tables:

Table 1: Heating Degrees Days (HDD) and Heating Design Temperature per zone in Minnesota

Minnesota	Zone 1	Zone 2	Zone 3
	(Northern MN)	(Central MN)	(Southern MN/Twin Cities)
HDD_{65} (ref. 6)	9,833	8,512	7,651
T_design (ref. 7)	-22 °F	-16.5 °F	-14.5 °F

Methodology and Assumptions:

Measurements and corrections must be performed with standard industry tools and practices; it is recommended that the results be tracked by the efficiency program.

Notes:

Actual tune-up cost may vary depending on contractor's tune-up procedure.

References:

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007 <http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf>

2. TBD

3. PA Consulting, KEMA, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that boilers are 30% oversized on average.

4. The correction factor corrects heating usage as building balance points are below 65F, and setback schedules are common. A typical heating degree day correction factor is 0.7. Assuming a typical building balance point temperature of 55F if was found that for a sampling of Minnesota cities HDD55 = 0.7 x HDD65.

5. TBD

6. National Climate Data Center - National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.

7. 2009 ASHRAE Fundamentals Handbook Table 1A Heating and Wind Design Conditions, Heating DB 99.6%

Document Revision History:

Version / Description	Author	Date
1 Replaces furnace tune-up measure in ResidentialFurnaceMeasures_v01; changed algorithm to match commercial boiler tune-up	JP	
1.1 Specified action, removed modification type from list of inputs from customer/vendor	JP	
1.2 Corrected error so that cost of tune-up is an optional input, increased cost of tune-up to $200	JP	
2.1 Changed savings equation	Franklin Energy	8/14/2012
2.2 Added Multi-family buildings to the measure	Franklin Energy	8/14/2012
2.3 Added efficiency standards	Franklin Energy	8/14/2012
2.4 Added references	Franklin Energy	8/14/2012
2.5 Changed wording of Btuh_input description	JP	4/3/2013

Residential HVAC - Programmable Thermostats with Gas Heating

Version No. 1.3

Measure Overview

Description: This measure includes replacement of failed or working manual thermostats in existing homes with programmable thermostats. New units must have the capability to adjust temperature setpoints according to a schedule without manual intervention. An estimate is provided for reduced heating energy consumption through temperature set-back during unoccupied or reduced demand times. Savings are provided for heating only as a literature review has not shown conclusive cooling savings.

Actions: Replace on Fail, Replace Working
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family homes, duplexes, townhomes, and multi-family homes (including 3- and 4-family homes) with residential type gas heating equipment. Gas must be the primary heating source to use this measure.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = HHCgas x HSF x HF x ISR

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 1)

Unit Participant Incremental Cost: $30 (Ref. 2)

Where:

HHCgas = Household heating consumption for natural gas heated single family homes, see Table 1. (Ref. 3)

HSF = Heating Savings Factor, assumed fraction reduction in heating energy consumption due to programmable thermostat, HSF = 0.062 (Ref. 4)

HF = Household factor, to adjust consumption for non-single family households, see Table 2. (Ref. 5)

ISR = In-Service Rate, the percentage of units installed and programmed effectively, Table 3. (Ref. 6)

Required from Customer/Contractor: Confirmation of gas heating, household type (see Table 2), program delivery type (see Table 3), location (county)

Examples:

Retrofit a manual thermostat with a programmable thermostat in a gas heated single family home in Climate Zone 3, via a prescriptive program delivery.

*Unit Dth Savings per Year = 66 * 0.062 *1.0 * 0.56 = 2.29 Dth*

Deemed Input Tables:

Table 1: Household heating consumption in residential homes per zone in Minnesota (Ref. 3)

Minnesota	Zone 1	Zone 2	Zone 3
Household Heating Consumption	(Northern MN)	(Central MN)	(Southern MN/Twin Cities)
HHCgas, Natural Gas Heating, Dth	83	72	66

Table 2: Household Factor (Ref. 5)

Household Type	HF
Single-Family	1.0
Duplexes, Townhomes, and Multifamily*	0.65

** Includes buildings with 3 or more units*

Table 3: In-Service Rates (Ref. 6)

Program Delivery	ISR
Direct Install	1.0
Other, or unknown	0.56

Methodology and Assumptions:

Primary assumption is having an existing manual thermostat replaced by a programmable thermostat, with a setback of at least 5 degrees each night. Households are assumed to be heated primarily by natural gas. Households with a combination of heating fuels may be addressed on a custom basis by proportioning the amount of electric and gas heat. As savings is dependent on household consumption, households with multiple thermostats shall not attain savings beyond that of the installation of one thermostat.

Notes:

Energy Star is developing a new specification for this measure category, if/when evaluation results demonstrate consistent cooling savings, subsequent versions of this measure will revisit potential cooling savings.

Upon adoption of International Energy Conservation Code (IECC) 2012 any new forced-air furnace system will require programmable thermostat control. This will become the baseline for new furnace installations.

References:

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007

http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

2. Market price vary significantly for this product, the basic functions required are available on units readily available in the market for the listed price. (Illinois Statewide Technical Reference Manual for Energy Efficiency Version 3.0, 2014)

3. Consumption values are based on 2012 Minnesota household electric and natural gas consumption in the three climate zones corrected for baseline usage and normalized for the typical heating season.

4. “Validating the Impacts of Programmable Thermostats, Final Report”, RWL Analytics, 2007

5. Multifamily household heating consumption relative to single family households is affected by overall square footage and exposure to the exterior. The 0.65 factor is applied to multifamily homes based on professional judgment that this represents average household size and heat loads. (Illinois Statewide Technical Reference Manual for Energy Efficiency Version 3.0, 2014)

6. “Programmable Thermostats. Report to KeySpan Energy Delivery on Energy and Cost Effectiveness,” GDS Associates, Marietta, GA. 2002

Document Revision History:

Version / Description	Author	Date
1.0 Measure Created	Franklin Energy	2/28/2014
1.1 Added duplex to multifamily category	JP	3/11/2014
1.2 Added IECC 2012 note	Franklin Energy	7/31/2014
1.3 In Methodology and Assumption, changed “solely” to”primarily” regarding gas heating for consistency with Description.	JP	7/31/2014

Residential Insulation and Air Sealing

Version No. 1.3

Measure Overview

Description:

This measure characterizes increased attic and/or wall insulation and air sealing for reduction of thermal losses through the building envelope.

The Minnesota Residential Energy Code requires that accessible attic bypasses be sealed prior to installing attic insulation (Ref. 8). Neglecting to seal bypasses can drastically reduce the effectiveness of insulation and lead to ice dams on the roof of the building during the winter. Ice dams can damage the roof and lead to water infiltration.

It is recommended that programs include pre- and post- blower door testing to measure the effectiveness of air sealing. Over-sealing a building can reduce natural ventilation to unsafe levels. The Minnesota Residential Energy Code specifies requirements for natural and mechanical ventilation to maintain acceptable air quality (Ref. 9). Programs should also include worst case draft testing of atmospherically-vented gas heating equipment following comprehensive air sealing and recommend installation of carbon monoxide detectors if not present.

Actions: Modify
Target Market Segments: Residential, Commercial
Target End Uses: Envelope

Applicable to: Residential and small commercial customers with natural gas heating. For existing buildings only.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = Wall Insulation Savings + Attic Insulation Savings + Air Sealing Savings

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years): 20 (Ref. 2)

Unit Participant Incremental Cost: See Table 3

Where:

Wall Insulation Savings (Dth) = ((1/R1_w - 1/R2_w) * A_w * (1-Framing_factor))*24*HDD/Eff)/1,000,000

Attic Insulation Savings (Dth) = ((1/R1_a – 1/R2_a) * A_a * (1-Framing_factor/2))*24*HDD/Eff)/1,000,000

Air Sealing Savings (Dth) = ((1.08 x 24 x HDD x CFM50 x CF/ N_heat)/ Eff)/1,000,000 (Ref. 3)

R1_w = R-value of old wall assembly (including all layers between inside air and outside air). (Minimum of R-5 for uninsulated assemblies.)

R2_w = R-value of new wall assembly (including all layers between inside air and outside air).

R1_a = R-value value of old assembly and any existing insulation (including all layers between inside air and outside air). (Minimum of R-5 for uninsulated assemblies.)

R2_a = R-value of new attic assembly (including all layers between inside air and outside air).

A_w = Total area of insulated wall (square feet)

A_a = Total area of insulated ceiling/attic (square feet)

Framing_factor = Adjustment factor to account for the area of framing materials = 15%

HDD65 = the heating degree days of the climate zone with a 65 degree base. See Table 1.

Eff = Efficiency of Heating System. Assume 80% if unknown.

CFM50 = Total reduction in Infiltration at 50 Pascals as measured by blower door. If unknown, use 1000.

CF = Correction factor. Assumed to be 0.7 (Ref. 7)

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions, based on climate, building height and exposure level (see Table 2)

1,000,000 = conversion factor: 1,000,000 Btu/Dth

Required from Customer/Contractor: Old and new R-values of attic (if applicable); Old and new R-values of wall (if applicable); confirmation of gas heating, relative exposure of building (well-shielded, normal, or exposed, if air sealing), no. of stories (if air sealing), project location (county).

Optional from Customer/Contractor: Efficiency of heating system, Infiltration before and after sealing as measured by blower door testing at 50 Pascals (if applicable). Blower door testing is recommended to measure effectiveness of air sealing.

Example:

A two-story single-family house with normal exposure in Zone 1 receives insulation and air sealing services. Cellulose insulation is blown into the 1,000 square foot attic to increase the R-value from 11 to 48. Air-sealing is performed to reduce infiltration. Pre- and post- blower door testing shows a decrease in CFM50 of 500. No wall insulation work is performed.

Wall Insulation Savings = 0

*Attic Insulation Savings = ((1/11 - 1/48) * 1,000 * (1 - 0.15/2) * 24 * 9,833 / 0.80) / 1,000,000 = 19.1 Dth*

*Air Sealing Savings = ((1.08 * 24 * 9,833 * 500 * 0.7 / 12.4) / 0.8) / 1,000,000 = 9.0 Dth*

Unit Dth Savings per Year = 0+19.1+9.0 = 28.1 Dth

Deemed Input Tables:

Table 1: Heating Degrees Days (HDD) per zone in Minnesota

Minnesota	Zone 1	Zone 2	Zone 3
	(Northern MN)	(Central MN)	(Southern MN / Twin Cities)
HDD65 (Ref. 5)	9,833	8,512	7,651

Table 2: N_heat for Minnesota, based on relative Wind Shielding Correction Factors and Height Correction Factors (Ref. 2)

Relative Exposure	Building Height (Stories)		
(see definitions below)	1	2	3
Well Shielded	18.6	14.9	13.0
Normal	15.5	12.4	10.9
Exposed	14.0	11.2	9.8

Well shielded: urban areas with buildings or sheltered areas. Buildings surrounded by trees, bermed earth, or higher terrain.

Normal: buildings in a residential neighborhood or subdivision setting, with yard space between buildings.

Exposed: buildings in an open setting with few buildings or trees around; buildings on top of a high hill, exposed to winds.

Table 3: Incremental Costs of Insulation (Ref. 6)

Insulation Type	Incremental Cost ($ / Square Foot)
Roof/Ceiling Insulation	$1.36
Wall Insulation	$0.94

Methodology and Assumptions:

The potential summer cooling electric savings from this measure is ignored, as the cooling hours in this area are limited, and customers may not use central cooling.

Notes:

There are statewide energy codes related to minimum insulation values of newly constructed and renovated commercial and residential buildings. There may also local building codes in place.

Energy codes pertaining to insulation, air sealing, and ventilation should be verified for each utility or location.

Minnesota is expected to adopt a new residential energy codes in 2014 referencing the 2012 International Energy Conservation Code.

References:

1. All insulation algorithms in this work paper come from the Illinois Statewide Technical Reference Manual, Sections 7.6.1 and 7.6.4, July 18, 2012

2. 2008 Database for Energy-Efficient Resources, Version 2008.2.04 October 30, 2008, EUL/RUL (Effective/Remaining Useful Life) Values

3. Air sealing algorithms from Building Energy Solutions, Inc., Explanation of Blower Door Terms and Results. This source cites another document: TECTITE BUILDING AIRTIGHTNESS TEST by The Energy Conservatory, which is not publicly available.

4. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

5. National Climate Data Center - National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.

6. 2008 Database for Energy-Efficient Resources, Revised DEER Measure Cost Summary, June 2, 2008

7. The correction factor corrects heating usage as building balance points are below 65F, and setback schedules are common. A typical heating degree day correction factor is 0.7. Assuming a typical building balance point temperature of 55F if was found that for a sampling of Minnesota cities HDD55 = 0.7 x HDD65.

8. 2006 International Residential Code Section N1101 as amended by Minnesota Residential Energy Code (Minn. Rules chapter 1322.1101.)

9. 2006 International Residential Code Section R303, as incorporated by Minnesota Residential Energy Code (Minn. Rules chapter 1322).

10. 2006 International Residential Code Section N1104 as amended by Minnesota Residential Energy Code (Minn. Rules chapter 1322.1104.)

Documentation Revision History :

Version/Description	Author	Date
1. Original Document	FES	7/31/2012
1.1 Changed Action to Modify	JP	11/24/13
1.2 Added “confirmation of gas heating system” to Required Inputs	JP	11/25/2013
1.3 Corrected required and optional inputs from customer/contractor, changed example to include air sealing, reformatted algorithm for clarity, modified description, added Commercial to market segment since also applicable to small commercial customers. Added definitions of shielding categories from FES.	JP	2/14/2014

Combined Electric and Gas Efficiency Measures

Commercial HVAC - Demand Control Ventilation

Version No. 1.2

Measure Overview

Description:

This measure includes the retro-fit of existing equipment or the optional addition of demand control ventilation.

This measure analyzes the cooling savings potential of the installation of demand control ventilation on unitary equipment.

This measure is applicable to dx and water cooled air systems.

The incremental cost is associated with CO2 sensor equipment cost and programming, the incremental cost does not include any damper actuator installation costs.

Actions: Replace Working (addition on working equipment)
Target Market Segments: Commercial & Industrial
Target End Uses: HVAC

Applicable to: Commercial & Industrial customers where air unitary equipment has been/could be installed.

Algorithms

Unit kWh Savings per Year = (4.5 x CFM x Δh) x (EFLH_cool x 12 / SEER) x SF_C / 3412

Unit Peak kW Savings = 0

Unit Dth Savings per Year = [(1.08 x CFM)/η x HDD65 x Hours] / 1,000,000 x SF_H

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years (ref 1)

Unit Participant Incremental Cost= See Table 2 (ref 2)

Where:

CFM = Outside Air flow in cubic feet per minute. Provided by customer.

Δh = Difference in enthalpy (Btu/lbm) between the design day outside air conditions (ref. 3) and the return air conditions (ref.4) See Table 1.

EFLH_cool = Effective full load cooling hours based on the building type. See Table 2. (ref. 5)

EER = Energy efficiency ratio of the existing equipment, provided by the customer. If unknown, use SEER = EER/0.875 (ref. 6) Assume EER = 10.9 in unavailable. (ref. 7)

Hours = Average hours per day of operation. Provided by customer.

HDD65 = Heating Degree Days See Table 1. (ref 8)

SF_C = Deemed cooling savings factor based upon building type. See Table 2. (ref. 9)

SF_H = Deemed Heating savings factor based upon building type. See Table 2. (ref. 9)

ΔT = Difference in temperature (°F) between the return air conditions (ref. 10) and the design day outside air conditions (ref. 11). See Table 1 for default values if not provided.

η = Efficiency of heating equipment. Assume 0.8 (ref 12) unless different efficiency is provided by owner.

1.08 = Conversion factor for flow rate and specific volume of air

4.5 = Conversion factor for BTU, flow rate and specific volume

1,000,000 = Conversion factor for BTU to Dth

Required from Customer/Contractor: Existing equipment type, existing equipment nominal cooling capacity in tons, existing equipment EER/SEER, building type (refer to Table 1), project location (county).

Example:

Install a CO2 senor in the return duct for a 10.5 EER packaged rooftop installed on a low rise office building open on average 12 hours per day in Climate Zone 3. OA supply existing is 1500 cfm

Unit KWh Savings per Year = (4.5 x 1500 x (36.3 - 28.8)) x (446 x 12 / (10.5/.875)) x 0.15 / 3412= 990 KWh

Unit Dth Savings per Year = ((1.08 x 1500) / 0.8 x 7651 x 12) / 1,000,000 x 0.18= 33 Dth

Deemed Input Tables:

Table 1: Enthalpies, heating degree days and incremental costs.

Zone #	Design Cooling h (Btu/lbm) (ref. 3)	Cooling Return h (Btu/lbm) (ref. 4)	HDD65 (°F-days) (ref. 8)	Incremental Cost (ref. 2)
Northern: #1	28.8	32.1	9883	$0.60/CFM
Central: #2	28.8	35.1	8512	$0.60/CFM
Southern: #3	28.8	36.3	7651	$0.60/CFM

Table 2: Cooling and Heating Savings Factors and Equivalent Full Load Hours of cooling per zone (ref. 5) in Minnesota by building type.

Building Type	SF_C (ref. 9)	SF_H (ref. 9)	EFLH - Zone 1	EFLH - Zone 2	EFLH - Zone 3
Convenience Store	0.34	0.40	647	825	986
Education - Community College /University	0.34	0.40	682	782	785
Education - Primary	0.34	0.40	289	338	408
Education - Secondary	0.34	0.40	484	473	563
Health/Medical - Clinic	0.29	0.34	558	738	865
Health/Medical - Hospital	0.34	0.40	663	1089	1298
Lodging	0.15	0.18*	401	606	754
Manufacturing	0.29	0.34	347	472	589
Office-Low Rise	0.15	0.18	257	359	446
Office-Mid Rise	0.15	0.18	373	529	651
Office-High Rise	0.15	0.18	669	1061	1263
Restaurant	0.34	0.40	347	535	652
Retail - Large Department Store	0.34	0.40	462	588	686
Retail - Strip Mall	0.34	0.40	307	441	574
Warehouse	0.31	0.36	164	343	409

*Value is applicable to Common Areas and Conference Rooms and not to sleeping areas

Methodology and Assumptions:

EFLH_Cool data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Assumed ventilation rates complied with the requirements of ASHRAE standard 62.1 - 2004.

Incremental costs include controls and programming and assume similar cost between dx and water cooled equipment.

Savings assume constant volume air system.

Assumes existing economizer operation and economizer operation is given preference over demand control ventilation strategy.

Assumes savings in hospitals and clinics is limited to those areas not having code required ACH of fresh air.

Gas savings algorithm is derived from the following:

Energy = Design Heating Load / Eff. x Equivalent full load hours x conversion

Where: Design Heating Load = (1.08 x CFM x ΔT), Equivalent full load hours = HDD65 x 24 / ΔT x Hours/24

ΔT = Difference in temperature (°F) between the return air conditions (ref. 5) and the design day outside air conditions

Unit Dth Savings per Year = ((1.08 x CFM x ΔT)/η x HDD65 x Hours /ΔT / 1,000,000 x SF_H

Unit Dth Savings per Year = ((1.08 x CFM)/η x HDD65 x Hours) / 1,000,000 x SF_H

Notes:

Current code does not require incorporation of demand control ventilation for all three Minnesota weather zones.

References:

1. Assumed Service life limited by controls and control life referenced from "Demand Control Ventilation Using CO2 Sensors", pg. 19, by US Department of Energy Efficiency and Renewable Energy

2. "Demand Control Ventilation Using CO2 Sensors", pg. 2, by US Department of Energy Efficiency and Renewable Energy and with an assumed zone size of 1500 Outside Air CFM

3. "Psychometric Chart at Barometric Pressure 29.921 Inches of Mercury", by Trane and ASHRAE 2009 Fundamentals Cooling DB/MCWB @ 0.4% averaged across zones

4. Assumed cooling set point of 74°F and 50% relative humidity with a 2°F temperature rise in the return plenum, FES

5. Calculated through energy modeling by FES 2012

6. "ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment"

7. "Small Commercial HVAC, Surveying the Frontier of Energy Efficiency", by Lee DeBallie, PE - Energy Center of Wisconsin

8. National Climate Data Center - National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.

9. Calculated through energy modeling by FES with certain building type SF modified based upon economizer operation hours. Savings where limited to 40% based upon professional experience due to concerns for negative building pressurization and minimum outside air requirements per sq. ft of occupied facility. Higher values may be obtained, but custom calculations would be required.

10. Assumed heating set point of 70°F, FES

11. 2009 ASHRAE Handbook HVAC Fundamentals

12. Assumed standard combustion efficiency of heating equipment, FES

Documentation Revision History:

Version	Description	Author	Date
1	New savings specification for retrofit/incorporation of demand control ventilation on air systems.	FES	
1.1	Changed heating algorithm by removing HDD and adding conversion factor of 365 days/year, clarified that Hours means average hours per day of operation over a full calendar to account for days when facility is closed.	JP	3.12.13
1.2	Corrected heating algorithm, added HDD back to Table 1, added derivation in Methodology & Assumptions	JP	3.27.13

Appendix A – Climate Zones

Weather-dependent measures in the Minnesota TRM reference three different climate zones which are illustrated in the map below. The boundaries follow county lines. The TRM is designed such that weather-dependent measures have county as a required input from customers or contractors. The county can be mapped to the climate zone using Table A-1.

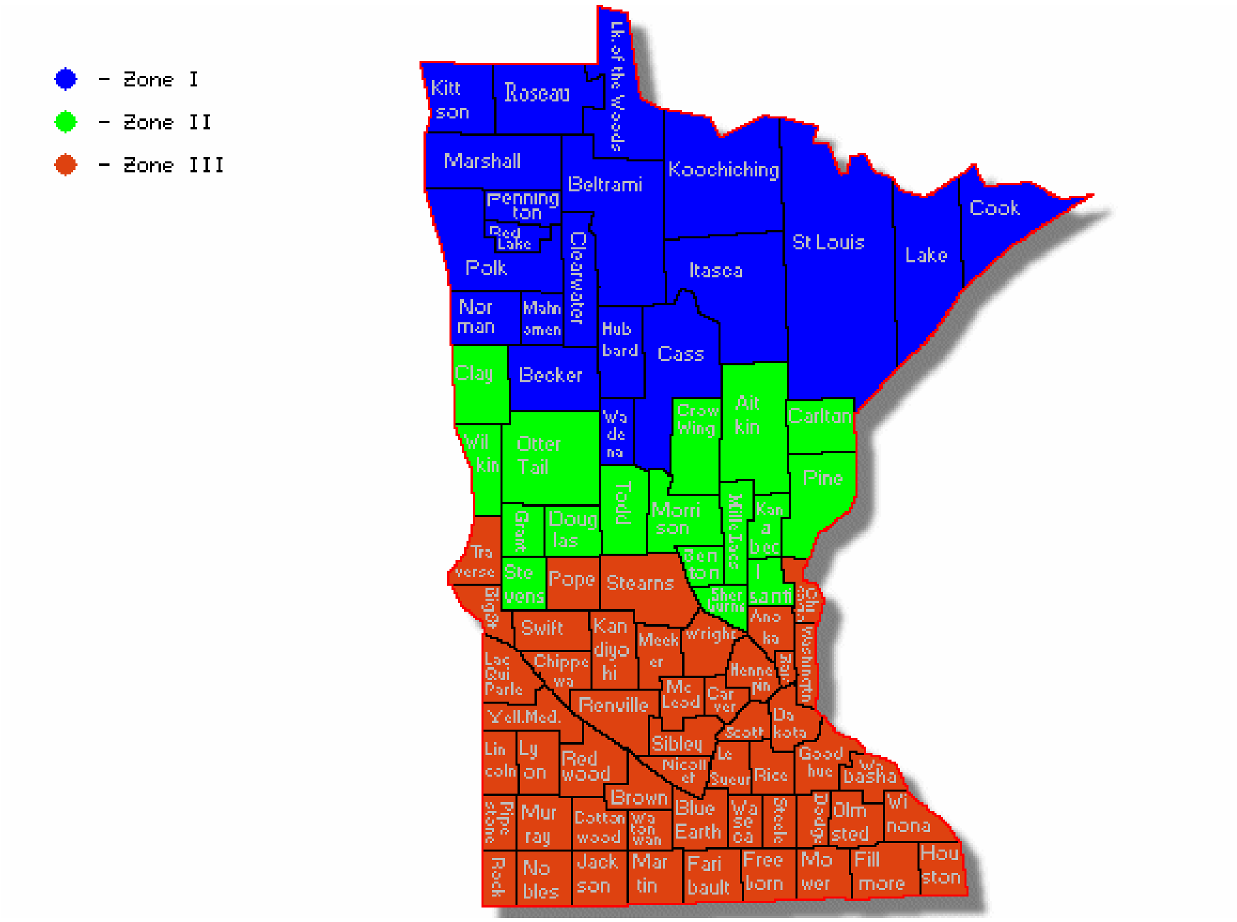

Figure A-1. Minnesota counties by climate zone (1, 2, and 3)

Table A-1. Minnesota counties by climate zone

	Zone 1	Zone 2	Zone 3	
Counties	Becker, Beltrami, Cass, Clearwater, Cook, Hubbard, Itasca, Kittson, Koochiching, Lake, Lake of the Woods, Mahnomen, Marshall, Norman, Pennington, Polk, Red Lake, Roseau, St. Louis, Wadena	Aitkin, Benton, Carlton, Clay, Crow Wing, Douglas, Grant, Isanti, Kanabec, Mille Lacs, Morrison, Otter Tail, Pine, Sherburne, Stevens, Todd, Wilkin	Anoka, Big Stone, Blue Earth, Brown, Carver, Chippewa, Chisago, Cottonwood, Dakota, Dodge, Faribault, Fillmore, Freeborn, Goodhue, Hennepin, Houston, Jackson, Kandiyohi, Lac qui Parle, Le Sueur, Lincoln, Lyon, McLeod, Martin, Meeker	Mower, Murray, Nicollet, Nobles, Olmsted, Pipestone, Pope, Ramsey, Redwood, Renville, Rice, Rock, Scott, Sibley, Stearns, Steele, Swift, Traverse, Wabasha, Waseca, Washington, Watonwan, Winona, Wright, Yellow Medicine

Appendix B – C/I Lighting Tables

Appendix B is available as a Microsoft Excel spreadsheet (*.xls) on the Minnesota Department of Commerce, Division of Energy Resources website. From the DER website, (http://mn.gov/commerce/energy/), please navigate to the ESP/TRM page under Conservation Improvement Program->Design Resources.

Appendix C – C/I Motor Tables

RPM	Enclosure	Horse-power	EPACT Efficiency	NEMA Premium Efficiency	Enhanced NEMA Premium Efficiency	Incr. Cost: EPACT to NEMA Premium	Incr. Cost: NEMA Premium to Enhanced	Incr. Cost: EPACT to Enhanced
1200	ODP	1	80.0%	82.5%	83.5%	$826.86	$311.97	$1,138.83
1200	ODP	1.5	84.0%	86.5%	87.5%	$821.85	$308.62	$1,130.47
1200	ODP	10	90.2%	91.7%	92.7%	$1,475.12	$745.15	$2,220.27
1200	ODP	100	94.1%	95.0%	96.0%	$8,402.69	$4,412.08	$12,814.77
1200	ODP	125	94.1%	95.0%	96.0%	$10,323.06	$5,695.32	$16,018.38
1200	ODP	15	90.2%	91.7%	92.7%	$2,541.29	$976.47	$3,517.75
1200	ODP	150	94.5%	95.4%	96.4%	$10,693.62	$5,942.94	$16,636.56
1200	ODP	2	85.5%	87.5%	88.5%	$907.18	$365.64	$1,272.82
1200	ODP	20	91.0%	92.4%	93.4%	$2,861.24	$1,190.27	$4,051.52
1200	ODP	200	94.5%	95.4%	96.4%	$12,801.47	$7,351.45	$20,152.92
1200	ODP	25	91.7%	93.0%	94.0%	$3,261.14	$1,457.50	$4,718.64
1200	ODP	250	95.4%	95.4%	96.4%	$15,888.00	$9,413.95	$25,301.95
1200	ODP	3	86.5%	88.5%	89.5%	$953.05	$396.29	$1,349.34
1200	ODP	30	92.4%	93.6%	94.6%	$3,513.58	$1,626.18	$5,139.75
1200	ODP	300	95.4%	95.4%	96.4%	$20,204.33	$12,298.23	$32,502.56
1200	ODP	350	95.4%	95.4%	96.4%	$29,220.28	$18,322.91	$47,543.19
1200	ODP	40	93.0%	94.1%	95.1%	$4,222.09	$2,099.62	$6,321.70
1200	ODP	400	95.8%	95.8%	96.8%	$32,992.47	$20,843.58	$53,836.05
1200	ODP	450	96.2%	96.2%	97.2%	$56,915.81	$36,829.75	$93,745.56
1200	ODP	5	87.5%	89.5%	90.5%	$976.06	$411.67	$1,387.72
1200	ODP	50	93.0%	94.1%	95.1%	$4,628.91	$2,371.47	$7,000.39
1200	ODP	500	96.2%	96.2%	97.2%	$59,663.64	$38,665.92	$98,329.55
1200	ODP	60	93.6%	94.5%	95.5%	$5,831.16	$3,174.84	$9,006.00
1200	ODP	7.5	88.5%	90.2%	91.2%	$1,323.26	$643.67	$1,966.93

1200	ODP	75	93.6%	94.5%	95.5%	$6,697.92	$3,754.03	$10,451.95
1200	TEFC	1	80.0%	82.5%	83.5%	$826.86	$311.97	$1,138.83
1200	TEFC	1.5	85.5%	87.5%	88.5%	$821.85	$308.62	$1,130.47
1200	TEFC	10	89.5%	91.0%	92.0%	$1,475.12	$745.15	$2,220.27
1200	TEFC	100	94.1%	95.0%	96.0%	$8,402.69	$4,412.08	$12,814.77
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1200	TEFC	200	95.0%	95.8%	96.8%	$12,801.47	$7,351.45	$20,152.92
1200	TEFC	25	91.7%	93.0%	94.0%	$3,261.14	$1,457.50	$4,718.64
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1200	TEFC	350	95.0%	95.8%	96.8%	$29,220.28	$18,322.91	$47,543.19
1200	TEFC	40	93.0%	94.1%	95.1%	$4,222.09	$2,099.62	$6,321.70
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1800	ODP	50	93.0%	94.5%	95.5%	$4,628.91	$2,371.47	$7,000.39
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1800	ODP	75	94.1%	95.0%	96.0%	$6,697.92	$3,754.03	$10,451.95
1800	TEFC	1	82.5%	85.5%	86.5%	$826.86	$311.97	$1,138.83
1800	TEFC	1.5	84.0%	86.5%	87.5%	$821.85	$308.62	$1,130.47
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1800	TEFC	200	95.0%	96.2%	97.2%	$12,801.47	$7,351.45	$20,152.92
1800	TEFC	25	92.4%	93.6%	94.6%	$3,261.14	$1,457.50	$4,718.64
1800	TEFC	250	95.0%	96.2%	97.2%	$15,888.00	$9,413.95	$25,301.95
1800	TEFC	3	87.5%	89.5%	90.5%	$953.05	$396.29	$1,349.34
1800	TEFC	30	92.4%	93.6%	94.6%	$3,513.58	$1,626.18	$5,139.75
1800	TEFC	300	95.4%	96.2%	97.2%	$20,204.33	$12,298.23	$32,502.56
1800	TEFC	350	95.4%	96.2%	97.2%	$29,220.28	$18,322.91	$47,543.19
1800	TEFC	40	93.0%	94.1%	95.1%	$4,222.09	$2,099.62	$6,321.70
1800	TEFC	400	95.4%	96.2%	97.2%	$32,992.47	$20,843.58	$53,836.05
1800	TEFC	450	95.4%	96.2%	97.2%	$56,915.81	$36,829.75	$93,745.56
1800	TEFC	5	87.5%	89.5%	90.5%	$976.06	$411.67	$1,387.72
1800	TEFC	50	93.0%	94.5%	95.5%	$4,628.91	$2,371.47	$7,000.39
1800	TEFC	500	95.8%	96.2%	97.2%	$59,663.64	$38,665.92	$98,329.55
1800	TEFC	60	93.6%	95.0%	96.0%	$5,831.16	$3,174.84	$9,006.00
1800	TEFC	7.5	89.5%	91.7%	92.7%	$1,323.26	$643.67	$1,966.93
1800	TEFC	75	94.1%	95.4%	96.4%	$6,697.92	$3,754.03	$10,451.95
3600	ODP	1	76.3%	77.0%	78.0%	$826.86	$311.97	$1,138.83
3600	ODP	1.5	82.5%	84.0%	85.0%	$821.85	$308.62	$1,130.47
3600	ODP	10	88.5%	89.5%	90.5%	$1,475.12	$745.15	$2,220.27
3600	ODP	100	93.0%	93.6%	94.6%	$8,402.69	$4,412.08	$12,814.77
3600	ODP	125	93.6%	94.1%	95.1%	$10,323.06	$5,695.32	$16,018.38
3600	ODP	15	89.5%	90.2%	91.2%	$2,541.29	$976.47	$3,517.75
3600	ODP	150	93.6%	94.1%	95.1%	$10,693.62	$5,942.94	$16,636.56
3600	ODP	2	84.0%	85.5%	86.5%	$907.18	$365.64	$1,272.82
3600	ODP	20	90.2%	91.0%	92.0%	$2,861.24	$1,190.27	$4,051.52
3600	ODP	200	94.5%	95.0%	96.0%	$12,801.47	$7,351.45	$20,152.92
3600	ODP	25	91.0%	91.7%	92.7%	$3,261.14	$1,457.50	$4,718.64
3600	ODP	250	94.5%	95.0%	96.0%	$15,888.00	$9,413.95	$25,301.95
3600	ODP	3	84.0%	85.5%	86.5%	$953.05	$396.29	$1,349.34
3600	ODP	30	91.0%	91.7%	92.7%	$3,513.58	$1,626.18	$5,139.75

3600	ODP	300	95.0%	95.4%	96.4%	$20,204.33	$12,298.23	$32,502.56
3600	ODP	350	95.0%	95.4%	96.4%	$29,220.28	$18,322.91	$47,543.19
3600	ODP	40	91.7%	92.4%	93.4%	$4,222.09	$2,099.62	$6,321.70
3600	ODP	400	95.4%	95.8%	96.8%	$32,992.47	$20,843.58	$53,836.05
3600	ODP	450	95.8%	95.8%	96.8%	$56,915.81	$36,829.75	$93,745.56
3600	ODP	5	85.5%	86.5%	87.5%	$976.06	$411.67	$1,387.72
3600	ODP	50	92.4%	93.0%	94.0%	$4,628.91	$2,371.47	$7,000.39
3600	ODP	500	95.8%	95.8%	96.8%	$59,663.64	$38,665.92	$98,329.55
3600	ODP	60	93.0%	93.6%	94.6%	$5,831.16	$3,174.84	$9,006.00
3600	ODP	7.5	87.5%	88.5%	89.5%	$1,323.26	$643.67	$1,966.93
3600	ODP	75	93.0%	93.6%	94.6%	$6,697.92	$3,754.03	$10,451.95
3600	TEFC	1	75.5%	77.0%	78.0%	$826.86	$311.97	$1,138.83
3600	TEFC	1.5	82.5%	84.0%	85.0%	$821.85	$308.62	$1,130.47
3600	TEFC	10	89.5%	90.2%	91.2%	$1,475.12	$745.15	$2,220.27
3600	TEFC	100	93.6%	94.1%	95.1%	$8,402.69	$4,412.08	$12,814.77
3600	TEFC	125	94.5%	95.0%	96.0%	$10,323.06	$5,695.32	$16,018.38
3600	TEFC	15	90.2%	91.0%	92.0%	$2,541.29	$976.47	$3,517.75
3600	TEFC	150	94.5%	95.0%	96.0%	$10,693.62	$5,942.94	$16,636.56
3600	TEFC	2	84.0%	85.5%	86.5%	$907.18	$365.64	$1,272.82
3600	TEFC	20	90.2%	91.0%	92.0%	$2,861.24	$1,190.27	$4,051.52
3600	TEFC	200	95.0%	95.4%	96.4%	$12,801.47	$7,351.45	$20,152.92
3600	TEFC	25	91.0%	91.7%	92.7%	$3,261.14	$1,457.50	$4,718.64
3600	TEFC	250	95.4%	95.8%	96.8%	$15,888.00	$9,413.95	$25,301.95
3600	TEFC	3	85.5%	86.5%	87.5%	$953.05	$396.29	$1,349.34
3600	TEFC	30	91.0%	91.7%	92.7%	$3,513.58	$1,626.18	$5,139.75
3600	TEFC	300	95.4%	95.8%	96.8%	$20,204.33	$12,298.23	$32,502.56
3600	TEFC	350	95.4%	95.8%	96.8%	$29,220.28	$18,322.91	$47,543.19
3600	TEFC	40	91.7%	92.4%	93.4%	$4,222.09	$2,099.62	$6,321.70
3600	TEFC	400	95.4%	95.8%	96.8%	$32,992.47	$20,843.58	$53,836.05
3600	TEFC	450	95.4%	95.8%	96.8%	$56,915.81	$36,829.75	$93,745.56

3600	TEFC	5	87.5%	88.5%	89.5%	$976.06	$411.67	$1,387.72
3600	TEFC	50	92.4%	93.0%	94.0%	$4,628.91	$2,371.47	$7,000.39
3600	TEFC	500	95.4%	95.8%	96.8%	$59,663.64	$38,665.92	$98,329.55
3600	TEFC	60	93.0%	93.6%	94.6%	$5,831.16	$3,174.84	$9,006.00
3600	TEFC	7.5	88.5%	89.5%	90.5%	$1,323.26	$643.67	$1,966.93
3600	TEFC	75	93.0%	93.6%	94.6%	$6,697.92	$3,754.03	$10,451.95

Appendix D – Commercial Building Models

The following table defines the characteristics of the models used for the C/I measures by Franklin Energy Services.

	Building Characteristics			General Occupancy Schedule				HVAC Equipment		
Building Type	Total Sq Ft	Number of Floors Above Grade	Secondary Spaces Breakdown (balance is primary space)	Weekday	Saturday	Sunday	Holiday	Air System	Cooling Equipment Type	Heating Equipment Type
Convenience Store	6,000	1	Office: 2%, Dry storage: 15%	7am-10pm	9am-9pm	10am-5pm	10am-5pm	Constant volume packaged rooftop unit	DX	Natural gas heater in RTU
Education - Community College/University	1,000,000	3	classrooms: 43.1%, ind work: 8%, computer rooms: 2.8%, corridor: 3%, dining: 2.4%, dorm: 17%, kitchen: 1.1%, office 22.7%	7am-Midnight (Typical Break Schedules - Summer Occupany 40%)	7am-7pm	10am-Noon	10am-Noon	Variable Air Volume (VAV), [constant volume packaged rooftop unit, kitchen]	Centrifigal Chiller, (DX Kitchen)	Boiler, hot water (Natural gas heater in RTU, kitchen)
Education - Primary	75,000	2	offices: 6%, gym 5%, kitchen 2%, cafeteria 5%, library: 6%	8am-4pm (20% in summer)	closed	closed	closed	Constant volume unit ventilators	Screw air cooled chiller	Boiler, hot water
Education - Secondary	225,000	2	gym: 10%, aux. gym 6%, auditorium 5%, kitchen 1%, cafeteria: 3%, offices 3%, library 4%	8am-4pm (20% in summer)	closed	closed	closed	Constant volume unit ventilators	Screw air cooled chiller	Boiler, hot water
Health/Medical - Clinic	67,500	3	30% exam, 30% corridor/lobby, 20% office, 20% storage/utility	7am-7pm	9am-5pm	closed	closed	Constant volume packaged rooftop unit	DX	Natural gas heater in RTU
Health/Medical - Hospital	200,000	4	56% lobby/corridor, 20% treatment rooms, 9% food service, 11% patient rooms, 3% office	24/7	24/7	24/7	24/7	Constant volume indoor units	Centrifugal water cooled chiller	Natural gas heater in RTU
Lodging	56,000	2	office: 3%, laundry 2.4%, Mtg room 2%, exercise 1%, employee lounge 1%	24/7	24/7	24/7	24/7	Packaged terminal heat pump	Packaged terminal AC	Heat pump, supplemental electric

Manufacturing Facility	120,000	1	10% office space on two floors, 90% manufacturing on single floor	Office: 8am-5pm, mfg: 6am-10pm	Office: closed, mfg: 6am-10pm	closed	closed	Mfg: Make-up air unit; Office: RTU	Mfg.: none; Office: DX	Natural gas heater in MAU & RTU
Office - High-rise	537,600	20		8am-5pm	20% 8am-noon	closed	closed	Variable Air Volume (VAV)	Centrifugal water cooled chiller	Boiler, hot water
Office - Low-rise	7,500	1		8am-5pm	closed	closed	closed	Constant volume packaged rooftop unit	DX	Natural gas heater in RTU
Office - Mid-rise	50,000	5		8am-5pm	20% 8am-noon	closed	closed	Variable Air Volume (VAV)	Centrifugal water cooled chiller	Boiler, hot water
Restaurant	7,500	1	kitchen 27%, dining 73%	7am-8pm	7am-8pm	7am-8pm	closed	Constant volume packaged rooftop unit	DX	Natural gas heater in RTU
Retail - Department Store	45,000	1	back space 17%, point of sale 7%	9am-9pm	9am-9pm	10am-5pm	10am-5pm	Constant volume packaged rooftop unit	DX	Natural gas heater in RTU
Retail - Strip Mall	3,000	1	storage: 15%	9am-9pm	9am-9pm	10am-5pm	10am-5pm	Constant volume packaged rooftop unit	DX	Natural gas heater in RTU
Warehouse	100,000	1	high bay storage: 80%, office 20%	6am-6pm	closed	closed	closed	Constant volume packaged rooftop unit	DX	Natural gas heater in RTU